IMPINGEMENT LOSSES AT THE D. C. COOK NUCLEAR POWER PLANT DURING 1975-1982 WITH A DISCUSSION OF FACTORS RESPONSIBLE AND POSSIBLE IMPACT ON LOCAL POPULATIONS

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INTRODUCTION

The Donald C. Cook Nuclear Power Plant is a 2,200 Mw utility on the southeastern shore of Lake Michigan near Bridgman, Michigan. Unit 1 (1,100 Mw), which began operation in 1975, requires 2.7 x 10^6 liters/min cooling water, while Unit 2, also 1,100 Mw, uses 3.6 x 10^6 liters/min. Though Unit 2 began operation in 1978, sustained pumping for a month or longer at full capacity did not occur until 1979. Cooling water enters through three intake cribs located 686 m offshore in 7.3 m of water, and heated water (with a calculated maximum ΔT of 12.1°C) is discharged through two slot-jet discharge structures located 366 m offshore in 5.5 m of water. With two units operating, water velocity at the intake crib is 0.4 m/s. Maximum water velocity is 1.8 m/s within the intake pipe. To prevent erosion and scour, a riprap bed (approximately 6 ha) of crushed limestone 0.1-1.0 m in diameter was deposited around the intake and discharge structures during plant construction.

Within the screenhouse, trash bars 6.6 cm apart prevent large debris from entering the forebay. Within the forebay, vertical traveling screens impinge trash and fish too large to pass through the 9.5-mm-bar mesh screens. Smaller organisms (mostly fish larvae and eggs, and zooplankton) are entrained with the cooling water and pass through the condensers. In addition to the terms "impingement" and "entrainment," "entrapment" in this report refers to fish entering the forebay through the intakes. Impingement is distinguished from entrapment because of the possibility that not all fish which enter the forebay are eventually impinged. To summarize, entrainment refers to those organisms present in the cooling water that pass through the traveling screens

and condensers, and are discharged back into the lake. All fish which enter the forebay and cannot pass through the traveling screens are considered to be entrapped. Some entrapped fish may make their way back to the lake. A fish is considered impinged when it is caught on the intake vertical traveling screens and sluiced into plant trash baskets.

This report contains annual estimates and species composition of fish impinged at the D. C. Cook Plant and compares them with similar data for field-caught fish for 1980-1982. Also discussed are seasonal and yearly trends in fish abundance and environmental and plant operation effects on rates of fish impingement. A previous report (Thurber and Jude 1984) discusses similar results from 1975-1979.

METHODS

Fish and debris from the traveling screens were separated by Cook Plant personnel. All fish were bagged, labeled with date and time, and then frozen. University of Michigan personnel collected and weighed all frozen fish; a 24-h sample was saved every fourth day and sorted by species and size. When many fish of the same size were collected in fourth-day samples, a subsample composed of up to 30 fish was randomly selected and remaining fish were weighed and discarded. All saved fish were measured to the nearest millimeter (total length), weighed to the nearest gram, and sexed; stomachs were examined for presence of food. Condition of gonads, presence of disease, or physical damage were also recorded.

Fourth-day samples (number and weight of fish) and weight of all fish impinged on interim days were used to estimate total monthly impingement

losses by species. Percent species composition (by weight) of fourth-day samples was used to partition the actual monthly weight of fish impinged into weight estimates by species, according to the formula:

$$E_w = (S_w/P_w)T_w$$

where:

E_w = Estimated monthly weight of fish impinged for a given species;

S_w = Monthly weight of fourth-day impingement samples for a given species;

P_w = Monthly weight of fourth-day impingement samples, all fish combined; and

T_w = Total monthly weight of all fish impinged (includes fourth-day and interim days).

Number of fish impinged per month was then estimated using

$$E_n = E_w/\bar{W}$$

where:

E_n = Estimated total number of fish impinged each month for a given species; and

$\bar{W}$ = Mean weight per fish of a given species, calculated for each species from number and weight of fish of each species impinged in fourth-day samples for a given month.

Offshore standard-series field samples were collected by gill net and bottom trawl from four stations: 6-m and 9-m stations at the Cook Plant and 6-m and 9-m stations at Warren Dunes State Park, about 11 km south of the Cook

Plant. Fish were seined from the beach zone at two stations near the Cook Plant (one north and one south of the plant), and at one station at Warren Dunes State Park.

Gill nets 160 x 1.8 m were set at offshore stations once per month for approximately 12 h during daylight and 12 h during the night. Catch was adjusted to catch per 12 h to standardize data (Jude et al. 1979). Nets were composed of 12 panels of netting as follows: 7.6-m sections of each of the following mesh sizes (bar measure) - 1.3 cm, 1.9 cm, and 2.5 cm; 15.2-m sections of mesh sizes 3.2-7.6 cm by 0.6-cm intervals; and a final 15.2-m section of 10-cm mesh. All gill nets were set parallel to shore on the bottom.

Duplicate, 10-min bottom tows were taken monthly both day and night at offshore stations, using a semi-balloon, nylon trawl having a 4.9-m headrope and a 5.8-m footrope. The body and cod end were composed respectively of 1.9-cm and 1.6-cm bar mesh, while the cod end interliner was 0.7-cm bar mesh. All trawl hauls were made at an average speed of 5 km/h, i.e., at a fixed rpm using the University of Michigan's R/V MYSIS. The trawl was towed parallel to shore following the 6- or 9-m depth contours; one haul was taken north to south and the other south to north at each depth contour.

Beach seining was usually conducted during periods of reduced wave height using a nylon seine 38 x 1.8 m with a 1.8 x 1.8-m bag; the entire seine had 0.64-cm bar mesh. The seine was first stretched perpendicular to the shoreline and then pulled parallel to shore a distance of 61 m. Duplicate, non-overlapping samples were taken in this manner both day and night once each month at beach stations. The seine was pulled against the current or

southerly when no current was detectable. When it was too difficult to pull the seine against the current, seining was done with the current.

Field-caught fish were processed in the same manner as impinged fish. For a more detailed discussion of field-sampling methods, see Jude et al. (1979), Tesar et al. (1985), and Tesar and Jude (1985). Common and scientific names of fish discussed in this paper are presented in Table 1.

RESULTS AND DISCUSSION

SPECIES COMPOSITION

The number of fish impinged annually at the Cook Plant during 1975-1982 ranged from 53,190 (1,833.34 kg) fish in 1977 to 2,307,654 (71,208.81 kg) fish in 1980 (Tables 2-17). Percent contributions that each species made to each year's total catch were averaged for 1975-1982; the fish most often impinged was the alewife (68% of total catch). Following in order of abundance were spottail shiner (10%), yellow perch (9%), trout-perch (5%), rainbow smelt (4%), and slimy sculpin (2%). Though averaging less than 1% over all years, bloaters increased in number during the study period and ranged from 0.02 to 4% of each year's total. None of the other less common species ever constituted more than 0.9% of the total number of fish impinged in any 1 year during 1975-1982 (Tables 2-17). Except for alewife, which was always impinged in highest numbers, rank order of the other species varied from year to year. During 1975-1982, 61 species were impinged (Tables 2-17). Nineteen species were impinged every year for all 8 years of the study, while 22 species were impinged during 4 years or less and were considered rare.

Table 1. Common and scientific names, and total estimated number of each species impinged during 1975-1982 at the D. C. Cook Nuclear Power Plant, southeastern Lake Michigan.

Common Name	Scientific Name	1975	1976	1977	1978	1979	1980	1981	1982
Alewife	*Alosa pseudoharengus*	174,341	114,958	31,498	238,133	330,709	1,815,490	1,415,821	831,051
Black bullhead	*Ictalurus melas*	35	45	16	12	4	9	35	68
Black crappie	*Pomoxis nigromaculatus*	11	4	7	2	5	6	5	9
Bloater	*Coregonus hoyi*	49	63	302	23,085	2,456	21,448	3,144	212
Bluegill	*Lepomis machrochirus*	48	23	10	11		12	73	37
Brown bullhead	*Ictalurus nebulosus*				11	4		7	6
Brown trout	*Salmo trutta*		37	24	61	95	120	166	176
Burbot	*Lota lota*	37	75	51	108	575	1,248	876	1,018
Central mudminnow	*Umbra limi*	9	9			5	24	43	66
Channel catfish	*Ictalurus punctatus*	50	70	27	26	50	87	175	87
Chestnut lamprey	*Ichthyomyzon castaneus*	4			5				
Chinook salmon	*Oncorhynchus tshawytscha*	7	16		59	729	875	22	23
Coho salmon	*Oncorhynchus kisutch*	8	22	22	78	165	63	44	530
Common carp	*Cyprinus carpio*	2	6		5	34	33	18	12
Deepwater sculpin	*Myoxocephalus thompsoni*	1	5				27	80	33
Emerald shiner	*Notropis atherinoides*	1			5				
Flathead catfish	*Pylodictis olivarus*						31		
Freshwater drum	*Aplodinotus grunniens*				18	2	4	3	8
Gizzard shad	*Dorosoma cepedianum*	278	1,780	35	692	252	669	1,682	1,925
Golden shiner	*Notemigonus crysoleucas*	5							9
Goldfish	*Carassius auratus*	2				5	4		
Grass pickerel	*Esox americanus vermiculatus*		1						
Green sunfish	*Lepomis cyanellus*	13	6	4	6		6	14	
Johnny darter	*Etheostoma nigum*	180	346	103	108	59	107	682	13
Lake chub	*Cousius plumbeus*		5	6	6		13		32
Lake chubsucker	*Erimyzon sucetta*			4		4			
Lake herring	*Coregonus artedii*								5
Lake sturgeon	*Acipenser fulvescens*						8		
Lake trout	*Salvelinus namaycush*	101	115	115	243	282	320	517	342
Lake whitefish	*Coregonus clupeaformis*	1				10	15	7	8
Largemouth bass	*Micropterus salmoides*	13	4	8		11	5		
Logperch	*Percina caprodes*	1							
Longnose dace	*Rhinichthys cataractae*	6	8	19	43		5	8	8
Longnose gar	*Lepisosteus osseus*								3
Longnose sucker	*Catostomus catostomus*	23	43	20	165	210	490	266	629
Mottled sculpin	*Cottus bairdi*			14	392	532	1,078	1,364	373
Ninespine stickleback	*Pungitius pungitius*	194	107	95	288	65	429	111	71
Northern pike	*Esox lucius*	3	17		5			17	7
Pirate perch	*Aphredoderus sayanus*	1							
Pumpkinseed	*Lepomis gibbosus*	23	32	2	15			5	9
Quillback	*Carpiodes cyprinus*	2							

Common Name	Scientific Name	1975	1976	1977	1978	1979	1980	1981	1982
Rainbow smelt	*Osmerus mordax*	3,746	2,772	1,488	51,013	35,398	149,085	112,837	13,863
Rainbow trout	*Salmo gairdneri*	4	17		6	14	20	37	24
Rock bass	*Ambloplites rupestris*	3	1	4	8	5	3	14	3
Round whitefish	*Prosopium cylindraceum*							39	
Sea lamprey	*Petromyzon marinus*					5	9	8	30
Shorthead redhorse	*Moxostoma macrolepidotum*			5	30	68		14	5
Silver redhorse	*Moxostoma anisurum*				5	11			
Slimy sculpin	*Cottus cognatus*	8,136	7,402	2,232	1,034	2,622	8,371	6,974	5,820
Smallmouth bass	*Micropterus dolomieui*	5	21	10	3	5	15	8	
Spottail shiner	*Notropis hudsonius*	9,985	24,104	5,032	178,009	52,761	106,009	86,260	33,842
Spotted sucker	*Minytrema melanops*	1						3	
Stonecat	*Noturus flavus*						11		
Tadpole madtom	*Noturus gyrinus*		5						6
Trout-perch	*Percopsis omiscomaycus*	15,373	10,357	4,826	88,692	15,002	31,063	23,711	1,998
Walleye	*Stizostedion vitreum vitreum*								6
Warmouth	*Lepomis gulosis*						2		
White crappie	*Pomoxis annularis*	6			11	2	5	18	
White sucker	*Catostomus commersoni*	16	27	14	186	271	173	141	584
Yellow bullhead	*Ictalurus natalis*	5	1	2				3	6
Yellow perch	*Perca flavescens*	12,006	21,309	7,195	32,811	38,349	170,262	391,983	38,811
		224,735	183,813	53,190	615,390	480,776	2,307,654	1,947,235	913,768

Table 2. Number of fish impinged on the D. C. Cook Plant traveling screens during 1975.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	193	1	1620	48997	22811	81840	11230	1910	458	2533	1016	1732	174341	77.58
Trout-perch	7	10	22	120	261	376	129	107	517	7327	5620	877	15373	6.84
Yellow perch	228	154	245	1195	45	313	400	492	414	4539	1816	2165	12006	5.34
Spottail shiner	86	261	345	961	748	701	117	44	318	1880	1980	2544	9985	4.44
Slimy sculpin	116	120	340	2959	1494	1171	436	321	357	261	294	267	8136	3.62
Rainbow smelt	8	11	75	873	1042	158	49	229	39	842	198	222	3746	1.67
Gizzard shad	1	13	10	33	0	0	0	0	0	4	64	153	278	0.12
Ninespine stickleback	1	0	9	69	86	20	2	0	1	3	0	3	194	0.09
Johnny darter	1	0	0	1	30	90	17	16	11	2	10	2	180	0.08
Lake trout	4	0	1	39	4	7	5	0	1	0	17	23	101	0.04
Channel catfish	16	4	10	12	0	3	1	1	1	0	0	2	50	0.02
Bloater	0	0	2	5	2	4	9	5	6	9	5	2	49	0.02
Bluegill	0	0	0	6	6	5	1	1	2	0	9	18	48	0.02
Burbot	2	1	3	5	4	6	1	4	2	4	2	3	37	0.02
Black bullhead	6	1	4	12	9	0	0	1	0	1	0	1	35	0.02
Longnose sucker	0	1	0	2	2	6	1	4	1	2	4	0	23	0.01
Pumpkinseed	0	0	0	0	0	1	0	0	0	2	4	16	23	0.01
White sucker	0	0	1	2	3	7	1	0	1	0	0	1	16	0.01
Largemouth bass	0	0	0	0	0	0	0	2	2	1	1	7	13	0.01
Green sunfish	0	0	0	0	0	0	0	0	0	1	1	11	13	0.01
Black crappie	0	0	0	0	0	0	0	0	0	1	2	8	11	<0.01
Central mudminnow	1	2	2	2	0	0	0	0	0	0	1	1	9	<0.01
Coho salmon	0	0	0	3	4	0	0	0	0	0	0	1	8	<0.01
Chinook salmon	0	0	0	3	0	0	3	1	0	0	0	0	7	<0.01
White crappie	1	0	0	0	0	0	0	0	0	1	0	4	6	<0.01
Longnose dace	0	0	0	1	0	0	0	0	0	1	4	0	6	<0.01
Golden shiner	0	0	1	3	0	0	0	0	0	0	1	0	5	<0.01
Smallmouth bass	1	0	0	0	0	0	0	0	2	0	1	1	5	<0.01
Yellow bullhead	0	1	0	0	0	0	0	0	0	0	3	1	5	<0.01
Rainbow trout	0	1	0	0	0	1	0	1	0	0	0	1	4	<0.01
Chestnut lamprey	0	0	0	2	1	0	0	1	0	0	0	0	4	<0.01
Northern pike	0	0	0	1	1	0	0	1	0	0	0	0	3	<0.01
Rock bass	0	0	0	2	0	0	0	0	0	0	1	0	3	<0.01
Common carp	0	0	0	0	0	0	0	2	0	0	0	0	2	<0.01
Goldfish	0	0	0	1	1	0	0	0	0	0	0	0	2	<0.01
Quillback	0	1	0	0	0	0	0	0	0	0	1	0	2	<0.01
Hybrid sunfish	0	0	1	0	0	0	0	0	0	0	0	0	1	<0.01
Emerald shiner	0	0	1	0	0	0	0	0	0	0	0	0	1	<0.01
Deepwater sculpin	0	0	0	1	0	0	0	0	0	0	0	0	1	<0.01
Lake whitefish	0	0	0	1	0	0	0	0	0	0	0	0	1	<0.01
Spotted sucker	0	0	0	0	0	0	0	0	0	0	0	1	1	<0.01
Pirate perch	0	0	0	1	0	0	0	0	0	0	0	0	1	<0.01
Logperch	0	0	0	0	1	0	0	0	0	0	0	0	1	<0.01
Totals	672	582	2692	55312	26555	84709	12402	3143	2133	17414	11055	8067	224736	

Table 3. Weight (kg) of fish impinged on the D. C. Cook Plant traveling screens in 1975. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	7.67	0.01	64.06	1842.97	797.75	2050.91	278.74	46.64	6.91	12.80	23.43	71.32	5203.20	84.87
Yellow perch	2.97	7.70	13.91	71.76	2.05	39.38	60.07	48.17	14.72	63.20	51.00	19.91	394.85	6.44
Trout-perch	0.05	0.16	0.24	1.22	2.69	3.24	1.14	1.10	3.48	71.53	71.41	11.86	168.13	2.74
Spottail shiner	0.98	3.37	3.91	11.85	7.17	7.54	1.10	0.48	2.63	15.44	15.19	18.23	87.90	1.43
Lake trout	13.35	0.0	0.02	0.80	3.88	0.08	0.11	0.0	0.02	0.0	25.04	43.09	86.39	1.41
Slimy sculpin	0.78	1.13	2.55	19.87	8.26	6.48	2.59	1.71	1.94	1.46	2.34	2.00	51.10	0.83
Rainbow smelt	0.15	0.20	0.68	12.65	17.48	1.76	0.43	0.98	0.24	1.30	1.41	2.37	39.66	0.65
Longnose sucker	0.0	1.77	0.0	2.86	3.03	8.87	0.92	3.62	1.07	1.69	5.95	0.0	29.78	0.49
Burbot	0.86	0.85	2.35	3.23	2.47	4.60	0.25	2.25	0.84	3.25	0.67	0.89	22.51	0.37
White sucker	0.0	0.0	0.91	1.40	2.84	8.99	1.31	0.0	0.90	0.0	0.0	0.02	16.38	0.27
Gizzard shad	0.01	0.45	0.81	6.69	0.0	0.0	0.0	0.0	0.0	0.02	0.39	1.69	10.06	0.16
Coho salmon	0.0	0.0	0.0	2.09	2.83	0.0	0.0	0.0	0.0	0.0	0.0	0.47	5.39	0.09
Northern pike	0.0	0.0	0.0	1.45	2.00	0.0	0.0	0.01	0.0	0.0	0.0	0.0	3.46	0.06
Lake whitefish	0.0	0.0	0.0	2.74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.74	0.04
Channel catfish	0.05	0.04	0.16	0.49	0.0	0.03	0.10	0.21	1.46	0.0	0.0	0.01	2.55	0.04
Black bullhead	0.24	0.01	0.30	0.75	0.73	0.0	0.0	0.06	0.0	0.08	0.0	0.05	2.22	0.04
Quillback	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.0	1.00	0.02
Johnny darter	0.00	0.0	0.0	0.00	0.10	0.26	0.04	0.04	0.03	0.00	0.03	0.01	0.51	0.01
Chinook salmon	0.0	0.0	0.0	0.46	0.0	0.0	0.01	0.02	0.0	0.0	0.0	0.0	0.49	0.01
Ninespine stickleback	0.00	0.0	0.02	0.16	0.20	0.04	0.00	0.0	0.00	0.01	0.0	0.01	0.45	0.01
Bloater	0.0	0.0	0.01	0.02	0.01	0.04	0.10	0.04	0.04	0.09	0.05	0.01	0.42	0.01
Rainbow trout	0.0	0.15	0.0	0.0	0.0	0.07	0.0	0.03	0.0	0.0	0.0	0.12	0.38	0.01
Pumpkinseed	0.0	0.0	0.0	0.0	0.0	0.07	0.0	0.0	0.0	0.00	0.08	0.08	0.23	<0.01
Bluegill	0.0	0.0	0.0	0.04	0.03	0.01	0.00	0.00	0.01	0.0	0.05	0.06	0.20	<0.01
Smallmouth bass	0.14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.00	0.02	0.17	<0.01
Chestnut lamprey	0.0	0.0	0.0	0.07	0.05	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.16	<0.01
Yellow bullhead	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.11	<0.01
Largemouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.01	0.00	0.05	0.09	<0.01
Rock bass	0.0	0.0	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.08	<0.01
Green sunfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.05	0.06	<0.01
Hybrid sunfish	0.0	0.0	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	<0.01
Central mudminnow	0.01	0.01	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.00	0.05	<0.01
Golden shiner	0.0	0.0	0.02	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.04	<0.01
Longnose dace	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.01	0.03	0.0	0.04	<0.01
Goldfish	0.0	0.0	0.0	0.03	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	<0.01
Black crappie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.01	0.02	0.03	<0.01
White crappie	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.02	0.03	<0.01
Deepwater sculpin	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	<0.01
Emerald shiner	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	<0.01
Spotted sucker	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	<0.01
Pirate perch	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	<0.01
Logperch	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	<0.01
Common carp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.0	0.00	<0.01
Totals	27.29	15.95	90.03	1983.74	853.58	2132.40	346.90	105.40	34.33	170.91	198.11	172.38	6131.00	

Table 4. Estimated number of fish impinged on the D. C. Cook Plant traveling screens in 1976. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	186	3	7748	5823	6603	31584	38813	9579	3373	2348	8644	254	114958	62.54
Spottail shiner	2330	1872	5602	2659	655	188	590	684	1702	2938	2152	2732	24104	13.11
Yellow perch	1663	111	221	438	277	331	2796	3840	5549	4106	198	1779	21309	11.59
Trout-perch	145	34	82	22	788	282	2871	1335	3843	679	155	121	10357	5.63
Slimy sculpin	252	106	494	2996	1667	290	376	452	368	150	112	139	7402	4.03
Rainbow smelt	240	75	197	808	569	45	268	210	8	116	86	150	2772	1.51
Gizzard shad	1161	72	63	0	0	0	0	0	8	27	310	139	1780	0.97
Johnny darter	0	1	0	22	129	15	32	11	94	19	17	6	346	0.19
Lake trout	8	10	30	0	24	11	0	0	0	0	9	23	115	0.06
Ninespine stickleback	5	3	6	0	72	0	0	0	0	4	17	0	107	0.06
Burbot	5	7	7	11	5	4	5	0	8	0	17	6	75	0.04
Channel catfish	22	12	11	0	0	4	0	0	0	4	0	17	70	0.04
Bloater	7	0	2	0	10	0	27	0	0	8	9	0	63	0.03
Black bullhead	2	1	7	11	5	0	0	0	0	4	9	6	45	0.02
Longnose sucker	2	4	4	11	0	0	0	22	0	0	0	0	43	0.02
Brown trout	0	0	0	11	5	0	0	0	0	0	9	12	37	0.02
Pumpkinseed	2	2	4	0	0	0	0	0	0	15	9	0	32	0.02
White sucker	4	2	0	0	0	8	5	0	8	0	0	0	27	0.01
Bluegill	2	0	0	0	0	4	0	0	0	8	9	0	23	0.01
Coho salmon	1	2	4	0	0	0	0	0	0	0	9	6	22	0.01
Smallmouth bass	0	0	0	0	0	0	0	0	0	0	9	12	21	0.01
Rainbow trout	0	1	0	0	5	0	5	0	0	0	0	6	17	0.01
Northern pike	2	0	0	0	0	4	0	11	0	0	0	0	17	0.01
Chinook salmon	0	0	2	0	10	4	0	0	0	0	0	0	16	0.01
Central mudminnow	0	0	9	0	0	0	0	0	0	0	0	0	9	<0.01
Longnose dace	3	1	0	0	0	0	0	0	0	4	0	0	8	<0.01
Green sunfish	2	0	0	0	0	4	0	0	0	0	0	0	6	<0.01
Common carp	4	0	2	0	0	0	0	0	0	0	0	0	6	<0.01
Deepwater sculpin	0	0	0	0	5	0	0	0	0	0	0	0	5	<0.01
Lake chub	0	1	0	0	0	0	0	0	4	0	0	0	5	<0.01
Tadpole madtom	0	0	0	0	0	0	5	0	0	0	0	0	5	<0.01
Black crappie	2	0	2	0	0	0	0	0	0	0	0	0	4	<0.01
Largemouth bass	0	0	0	0	0	0	0	0	4	0	0	0	4	<0.01
Hybrid sunfish	0	0	4	0	0	0	0	0	0	0	0	0	4	<0.01
Grass pickerel	0	1	0	0	0	0	0	0	0	0	0	0	1	<0.01
Yellow bullhead	0	1	0	0	0	0	0	0	0	0	0	0	1	<0.01
Rock bass	0	1	0	0	0	0	0	0	0	0	0	0	1	<0.01
Totals	6050	2323	14501	12812	10829	32778	45793	16144	14969	10430	11780	5408	183817	

Table 5. Estimated weight (kg) of fish impinged on the D. C. Cook Plant traveling screens in 1976. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	9.56	0.11	336.19	236.36	199.78	764.15	987.52	225.67	24.70	12.21	200.49	6.54	3003.31	60.96
Yellow perch	14.01	8.21	8.19	13.58	7.96	34.05	324.07	373.18	117.85	81.23	6.52	107.05	1095.91	22.24
Spottail shiner	18.09	17.04	52.74	28.27	5.41	2.04	5.28	6.21	14.96	30.38	19.73	31.39	231.55	4.70
Lake trout	19.25	9.02	7.46	0.0	41.01	18.86	0.0	0.0	0.0	0.0	23.68	75.94	195.21	3.96
Gizzard shad	31.57	23.87	1.77	0.0	0.0	0.0	0.0	0.0	2.29	0.26	2.97	23.48	86.21	1.75
Trout-perch	2.14	0.46	0.91	0.27	5.31	2.33	23.83	11.67	14.18	10.67	2.07	2.30	76.16	1.55
Rainbow smelt	2.57	1.27	2.57	23.29	4.94	0.54	3.27	4.32	0.13	0.58	1.19	2.07	46.72	0.95
Slimy sculpin	2.11	0.76	3.58	15.22	7.81	1.95	2.43	2.60	1.77	1.08	0.83	1.37	41.52	0.84
Burbot	2.15	3.76	6.77	10.78	2.39	0.19	2.50	0.0	1.63	0.0	7.34	1.91	39.42	0.80
Longnose sucker	2.42	6.18	2.86	18.51	0.0	0.0	0.0	0.21	0.0	0.0	0.0	0.0	30.19	0.61
White sucker	1.26	0.05	0.0	0.0	0.0	9.26	7.78	0.0	7.09	0.0	0.0	0.0	25.44	0.52
Northern pike	0.66	0.0	0.0	0.0	0.0	2.00	0.0	21.52	0.0	0.0	0.0	0.0	24.18	0.49
Coho salmon	0.65	0.98	1.27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.28	5.77	9.96	0.20
Brown trout	0.0	0.0	0.0	6.86	0.13	0.0	0.0	0.0	0.0	0.0	0.12	0.53	7.64	0.16
Black bullhead	0.02	0.08	0.44	0.19	0.05	0.0	0.0	0.0	0.0	0.15	1.54	2.31	4.79	0.10
Channel catfish	0.45	1.02	0.05	0.0	0.0	0.02	0.0	0.0	0.0	0.01	0.0	0.28	1.82	0.04
Bloater	0.05	0.0	0.03	0.0	0.45	0.0	1.10	0.0	0.0	0.03	0.04	0.0	1.69	0.03
Johnny darter	0.0	0.00	0.0	0.08	0.42	0.04	0.06	0.01	0.18	0.05	0.02	0.01	0.89	0.02
Rainbow trout	0.0	0.13	0.0	0.0	0.06	0.0	0.17	0.0	0.0	0.0	0.0	0.53	0.89	0.02
Smallmouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.15	0.51	0.65	0.01
Chinook salmon	0.0	0.0	0.27	0.0	0.33	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.61	0.01
Black crappie	0.49	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.50	0.01
Pumpkinseed	0.00	0.00	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.36	0.0	0.41	0.01
Ninespine stickleback	0.01	0.01	0.01	0.0	0.17	0.0	0.0	0.0	0.0	0.01	0.04	0.0	0.25	0.01
Bluegill	0.01	0.0	0.0	0.0	0.0	0.07	0.0	0.0	0.0	0.09	0.04	0.0	0.21	<0.01
Rock bass	0.0	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.15	<0.01
Common carp	0.10	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.11	<0.01
Longnose dace	0.04	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.10	<0.01
Hybrid sunfish	0.0	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	<0.01
Grass pickerel	0.0	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	<0.01
Green sunfish	0.02	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.05	<0.01
Largemouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	0.0	0.0	0.0	0.05	<0.01
Central mudminnow	0.0	0.0	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	<0.01
Tadpole madtom	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.03	<0.01
Lake chub	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.01	<0.01
Deepwater sculpin	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	<0.01
Yellow bullhead	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	<0.01
Totals	107.63	73.21	425.29	353.42	276.23	835.55	1358.05	645.40	184.86	136.85	268.41	261.99	4926.89	

Table 6. Estimated number of fish impinged on the D. C. Cook Plant traveling screens in 1977. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	7	0	512	2516	3892	15816	1629	219	888	5323	194	502	31498	59.22
Yellow perch	10	48	1045	606	51	184	3592	329	144	463	272	451	7195	13.53
Spottail shiner	4	41	1990	1507	220	71	303	37	69	408	147	235	5032	9.46
Trout-perch	1	8	24	141	46	226	1202	119	208	2625	118	108	4826	9.07
Slimy sculpin	6	3	184	1323	363	205	45	9	29	29	13	23	2232	4.20
Rainbow smelt	8	41	112	291	113	120	306	9	17	385	36	50	1488	2.80
Bloater	0	1	0	0	0	14	13	0	0	239	8	27	302	0.57
Lake trout	5	1	8	10	15	0	0	0	0	7	27	42	115	0.22
Johnny darter	0	0	0	15	51	28	5	0	0	4	0	0	103	0.19
Ninespine stickleback	1	0	8	39	36	7	0	0	0	4	0	0	95	0.18
Burbot	0	1	0	0	10	14	5	9	6	0	6	0	51	0.10
Gizzard shad	5	0	0	0	0	0	0	0	0	11	11	8	35	0.07
Channel catfish	7	4	12	0	0	0	0	0	0	4	0	0	27	0.05
Brown trout	9	3	0	10	0	0	0	0	0	0	2	0	24	0.05
Coho salmon	2	1	4	5	0	0	0	0	0	0	2	8	22	0.04
Longnose sucker	0	0	0	0	0	0	20	0	0	0	0	0	20	0.04
Longnose dace	0	0	0	0	0	0	0	0	0	4	0	15	19	0.04
Black bullhead	0	0	16	0	0	0	0	0	0	0	0	0	16	0.03
Mottled sculpin	0	0	0	0	0	0	0	0	0	0	2	12	14	0.03
White sucker	0	0	0	0	0	0	0	0	6	0	4	4	14	0.03
Smallmouth bass	0	0	4	0	0	0	0	0	0	0	2	4	10	0.02
Bluegill	0	0	0	0	0	0	0	0	0	0	2	8	10	0.02
Largemouth bass	1	0	0	0	0	0	3	0	0	4	0	0	8	0.02
Black crappie	0	0	0	0	0	0	0	0	0	7	0	0	7	0.01
Lake chub	0	0	0	0	0	0	0	0	0	0	2	4	6	0.01
Shorthead redhorse	0	1	0	0	0	0	0	0	0	0	0	4	5	0.01
Lake chubsucker	0	0	4	0	0	0	0	0	0	0	0	0	4	0.01
Green sunfish	0	0	4	0	0	0	0	0	0	0	0	0	4	0.01
Rock bass	0	0	0	0	0	0	0	0	0	4	0	0	4	0.01
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	2	0	2	<0.01
Yellow bullhead	2	0	0	0	0	0	0	0	0	0	0	0	2	<0.01
Totals	68	153	3927	6463	4797	16685	7123	731	1367	9521	850	1505	53190	

Table 7. Estimated weight (kg) of fish impinged on the D. C. Cook Plant traveling screens in 1977. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0.14	0.0	20.87	93.10	124.48	405.06	40.50	6.37	9.98	32.61	1.87	19.60	754.57	41.16
Yellow perch	2.59	2.58	20.00	35.89	2.84	32.81	330.99	36.30	9.77	5.93	9.27	9.75	498.73	27.20
Lake trout	17.50	4.00	35.01	27.39	52.98	0.0	0.0	0.0	0.0	28.38	96.86	147.69	409.82	22.35
Spottail shiner	0.06	0.61	26.21	19.59	2.57	0.67	2.89	0.47	0.56	2.98	1.45	2.04	60.09	3.28
Trout-perch	0.01	0.11	0.27	1.38	0.48	1.56	5.29	0.86	1.62	20.99	1.30	1.12	34.99	1.91
Burbot	0.0	1.12	0.0	0.0	5.40	3.55	1.88	2.20	2.19	0.0	4.49	0.0	20.82	1.14
Slimy sculpin	0.06	0.04	1.87	8.55	1.86	1.11	0.28	0.08	0.27	0.31	0.11	0.23	14.79	0.81
Coho salmon	1.25	0.98	2.69	2.19	0.0	0.0	0.0	0.0	0.0	0.0	0.48	5.24	12.84	0.70
Rainbow smelt	0.13	0.42	0.73	3.16	0.82	1.18	1.21	0.05	0.04	3.13	0.45	0.64	11.98	0.65
White sucker	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.76	0.0	2.67	0.13	7.57	0.41
Gizzard shad	1.44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	0.14	0.29	1.91	0.10
Bloater	0.0	0.01	0.0	0.0	0.0	0.21	0.13	0.0	0.0	0.95	0.05	0.25	1.60	0.09
Brown trout	0.45	0.15	0.0	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.0	0.85	0.05
Shorthead redhorse	0.0	0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.59	0.79	0.04
Johnny darter	0.0	0.0	0.0	0.06	0.18	0.06	0.01	0.0	0.0	0.01	0.0	0.0	0.33	0.02
Channel catfish	0.17	0.08	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.31	0.02
Ninespine stickleback	0.00	0.0	0.03	0.10	0.09	0.02	0.0	0.0	0.0	0.01	0.0	0.0	0.24	0.01
Black bullhead	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.22	0.01
Smallmouth bass	0.0	0.0	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.14	0.21	0.01
Longnose dace	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.12	0.14	0.01
Mottled sculpin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.11	0.13	0.01
Longnose sucker	0.0	0.0	0.0	0.0	0.0	0.0	0.12	0.0	0.0	0.0	0.0	0.0	0.12	0.01
Rock bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08	0.0	0.0	0.08	<0.01
Lake chubsucker	0.0	0.0	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07	<0.01
Largemouth bass	0.03	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.04	<0.01
Lake chub	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.03	<0.01
Black crappie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.02	<0.01
Green sunfish	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	<0.01
Yellow bullhead	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	<0.01
Pumpkinseed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.01	<0.01
Bluegill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.01	0.01	<0.01
Totals	23.85	10.29	108.07	191.55	191.70	446.24	383.31	46.34	29.19	95.50	119.31	187.98	1833.34	

Table 8. Estimated number of fish impinged on the D. C. Cook Plant traveling screens in 1978. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	0	0	8	4438	52824	156016	10447	4140	6154	2687	1419	238133	38.70
Spottail shiner	4204	145	959	2256	610	1147	149282	6639	5360	5031	496	1880	178009	28.93
Trout-perch	170	5	35	19	477	1319	79256	2835	2163	2235	33	145	88692	14.41
Rainbow smelt	170	15	1118	55	3432	1096	27865	16468	675	51	0	68	51013	8.29
Yellow perch	795	26	363	343	57	236	20532	5254	1950	607	2404	244	32811	5.33
Bloater	6	0	0	0	0	38	21981	767	18	138	33	104	23085	3.75
Slimy sculpin	50	11	22	131	415	57	132	42	18	20	0	136	1034	0.17
Gizzard shad	19	0	3	0	0	0	6	0	0	225	82	357	692	0.11
Mottled sculpin	88	5	3	0	33	19	6	23	92	51	0	72	392	0.06
Ninespine stickleback	13	0	48	5	138	51	19	5	0	0	0	9	288	0.05
Lake trout	0	7	10	3	10	6	0	5	9	36	71	86	243	0.04
White sucker	6	0	3	0	5	0	32	19	0	107	0	14	186	0.03
Longnose sucker	19	4	13	14	5	32	25	5	18	10	11	9	165	0.03
Burbot	6	7	13	8	5	0	6	14	9	31	0	9	108	0.02
Johnny darter	0	0	3	0	10	19	57	19	0	0	0	0	108	0.02
Coho salmon	6	5	19	14	10	6	13	0	0	5	0	0	78	0.01
Brown trout	6	2	3	0	0	0	0	0	9	0	0	41	61	0.01
Chinook salmon	0	0	0	3	0	6	13	0	0	0	5	32	59	0.01
Longnose dace	25	0	0	0	0	0	0	0	0	0	0	18	43	0.01
Shorthead redhorse	0	0	3	0	0	0	0	0	0	0	0	27	30	<0.01
Channel catfish	13	0	0	3	0	0	0	0	0	10	0	0	26	<0.01
Freshwater drum	0	0	0	0	0	0	0	0	18	0	0	0	18	<0.01
Pumpkinseed	0	0	0	0	0	0	6	0	9	0	0	0	15	<0.01
Black bullhead	0	0	0	3	0	0	0	0	0	0	0	9	12	<0.01
White crappie	0	0	0	0	0	0	6	0	0	5	0	0	11	<0.01
Bluegill	0	0	0	0	0	0	6	0	0	5	0	0	11	<0.01
Brown bullhead	0	0	0	0	0	6	0	0	0	0	0	5	11	<0.01
Rock bass	6	2	0	0	0	0	0	0	0	0	0	0	8	<0.01
Rainbow trout	0	0	6	0	0	0	0	0	0	0	0	0	6	<0.01
Lake chub	6	0	0	0	0	0	0	0	0	0	0	0	6	<0.01
Green sunfish	0	0	0	0	0	0	6	0	0	0	0	0	6	<0.01
Chestnut lamprey	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Common carp	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Silver redhorse	0	0	0	0	0	0	0	0	0	5	0	0	5	<0.01
Northern pike	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Emerald shiner	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Smallmouth bass	0	0	0	3	0	0	0	0	0	0	0	0	3	<0.01
Black crappie	0	2	0	0	0	0	0	0	0	0	0	0	2	<0.01
Totals	5608	236	2624	2868	9645	56862	455265	42542	14488	14726	5822	4704	615390	

Table 9. Estimated weight (kg) of fish impinged on the D. C. Cook Plant traveling screens in 1978. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0.0	0.0	0.0	0.39	174.01	1295.92	3804.72	240.88	56.98	77.95	93.66	63.52	5808.02	55.44
Yellow perch	42.45	3.33	46.30	44.16	4.67	11.13	642.54	417.23	115.70	60.20	42.51	16.78	1447.01	13.81
Lake trout	0.0	26.03	26.24	8.72	31.46	21.02	0.0	24.79	30.73	138.47	248.17	302.36	858.00	8.19
Spottail shiner	50.76	1.46	12.70	33.65	6.22	8.15	466.54	46.09	37.48	42.86	4.02	19.84	729.79	6.97
Trout-perch	1.31	0.05	0.27	0.15	3.70	9.60	391.03	19.58	15.32	23.48	0.36	1.44	466.30	4.45
Bloater	0.03	0.0	0.0	0.0	0.0	0.19	235.38	8.63	0.09	0.67	0.17	0.52	245.68	2.35
Rainbow smelt	3.17	0.37	19.71	1.18	22.45	4.91	92.79	79.10	5.39	1.53	0.0	0.32	230.91	2.20
Longnose sucker	17.57	6.14	25.83	24.84	6.08	31.28	35.96	3.28	3.05	17.86	14.58	15.95	202.42	1.93
White sucker	0.22	0.0	6.37	0.0	5.24	0.0	34.95	15.49	0.0	50.53	0.0	10.03	122.83	1.17
Gizzard shad	1.13	0.0	1.67	0.0	0.0	0.0	5.08	0.0	0.0	16.68	1.81	36.89	63.26	0.60
Chinook salmon	0.0	0.0	0.0	0.67	0.0	0.04	0.10	0.0	0.0	0.0	52.33	5.68	58.83	0.56
Brown trout	0.57	0.18	0.40	0.0	0.0	0.0	0.0	0.0	50.83	0.0	0.0	3.24	55.22	0.53
Coho salmon	5.21	3.62	12.01	11.56	9.45	6.37	0.82	0.0	0.0	1.71	0.0	0.0	50.76	0.48
Burbot	1.74	3.86	6.92	3.25	2.02	0.0	3.97	6.63	8.78	12.70	0.0	0.53	50.40	0.48
Channel catfish	0.54	0.0	0.0	1.82	0.0	0.0	0.0	0.0	0.0	20.43	0.0	0.0	22.78	0.22
Common carp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.53	17.53	0.17
Freshwater drum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.17	0.0	0.0	0.0	10.17	0.10
Shorthead redhorse	0.0	0.0	0.66	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.00	7.67	0.07
Slimy sculpin	0.80	0.09	0.18	1.19	2.36	0.33	0.75	0.14	0.19	0.21	0.0	1.33	7.57	0.07
Silver redhorse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.14	0.0	0.0	7.14	0.07
Mottled sculpin	1.31	0.04	0.06	0.0	0.65	0.15	0.05	0.15	1.10	0.43	0.0	0.97	4.91	0.05
Northern pike	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.39	1.39	0.01
Smallmouth bass	0.0	0.0	0.0	1.37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.37	0.01
Rainbow trout	0.0	0.0	1.16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.16	0.01
Ninespine stickleback	0.04	0.0	0.16	0.01	0.42	0.12	0.03	0.01	0.0	0.0	0.0	0.03	0.83	0.01
Brown bullhead	0.0	0.0	0.0	0.0	0.0	0.63	0.0	0.0	0.0	0.0	0.0	0.09	0.72	0.01
White crappie	0.0	0.0	0.0	0.0	0.0	0.0	0.49	0.0	0.0	0.12	0.0	0.0	0.61	0.01
Black bullhead	0.0	0.0	0.0	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.33	0.48	<0.01
Longnose dace	0.28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.17	0.44	<0.01
Chestnut lamprey	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.29	0.29	<0.01
Johnny darter	0.0	0.0	0.01	0.0	0.02	0.05	0.13	0.05	0.0	0.0	0.0	0.0	0.27	<0.01
Rock bass	0.07	0.18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.25	<0.01
Black crappie	0.0	0.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12	<0.01
Pumpkinseed	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.10	0.0	0.0	0.0	0.11	<0.01
Bluegill	0.0	0.0	0.0	0.0	0.0	0.0	0.07	0.0	0.0	0.03	0.0	0.0	0.10	<0.01
Green sunfish	0.0	0.0	0.0	0.0	0.0	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.08	<0.01
Lake chub	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	<0.01
Emerald shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.02	<0.01
Totals	127.24	45.46	160.67	133.13	268.76	1389.90	5715.46	862.07	335.89	472.99	457.62	506.24	10475.44	

Table 10. Estimated number of fish impinged on the D. C. Cook Plant traveling screens in 1979. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	10	0	5	871	18	82	108157	62215	154201	3178	42	1930	330709	68.79
Spottail shiner	5176	347	676	8956	25	0	3630	9845	14007	9840	72	187	52761	10.97
Yellow perch	1315	184	585	308	14	0	580	4094	29843	1271	20	135	38349	7.98
Rainbow smelt	382	33	463	3317	11	0	6363	7978	16158	657	5	31	35398	7.36
Trout-perch	314	43	36	271	4	0	3580	3808	3439	3432	28	47	15002	3.12
Slimy sculpin	152	49	249	1788	18	0	151	105	16	42	0	52	2622	0.55
Bloater	31	0	5	0	0	0	2244	45	59	64	3	5	2456	0.51
Chinook salmon	10	11	631	21	0	0	7	45	4	0	0	0	729	0.15
Burbot	231	65	127	38	22	0	18	15	14	42	3	0	575	0.12
Mottled sculpin	183	22	10	0	0	0	29	196	20	53	3	16	532	0.11
Lake trout	37	16	0	0	4	0	0	45	14	106	18	42	282	0.06
White sucker	52	38	51	33	7	20	4	45	0	21	0	0	271	0.06
Gizzard shad	47	5	5	0	0	0	0	15	4	138	2	36	252	0.05
Longnose sucker	16	11	51	29	11	0	18	30	5	32	7	0	210	0.04
Coho salmon	16	0	81	54	14	0	0	0	0	0	0	0	165	0.03
Brown trout	26	16	36	17	0	0	0	0	0	0	0	0	95	0.02
Shorthead redhorse	37	16	15	0	0	0	0	0	0	0	0	0	68	0.01
Ninespine stickleback	10	0	5	46	0	0	4	0	0	0	0	0	65	0.01
Johnny darter	0	0	0	0	0	0	7	45	7	0	0	0	59	0.01
Channel catfish	21	11	5	8	0	0	0	0	5	0	0	0	50	0.01
Common carp	0	0	15	0	4	0	0	15	0	0	0	0	34	0.01
Rainbow trout	0	0	10	4	0	0	0	0	0	0	0	0	14	<0.01
Silver redhorse	0	0	0	0	0	0	0	0	0	11	0	0	11	<0.01
Largemouth bass	0	0	0	0	0	0	0	0	0	11	0	0	11	<0.01
Lake whitefish	5	0	5	0	0	0	0	0	0	0	0	0	10	<0.01
Goldfish	0	5	0	0	0	0	0	0	0	0	0	0	5	<0.01
Central mudminnow	0	0	5	0	0	0	0	0	0	0	0	0	5	<0.01
Sea lamprey	0	0	5	0	0	0	0	0	0	0	0	0	5	<0.01
Smallmouth bass	0	0	5	0	0	0	0	0	0	0	0	0	5	<0.01
Black crappie	5	0	0	0	0	0	0	0	0	0	0	0	5	<0.01
Rock bass	0	0	5	0	0	0	0	0	0	0	0	0	5	<0.01
Lake chubsucker	0	0	0	4	0	0	0	0	0	0	0	0	4	<0.01
Black bullhead	0	0	0	4	0	0	0	0	0	0	0	0	4	<0.01
Brown bullhead	0	0	0	4	0	0	0	0	0	0	0	0	4	<0.01
White crappie	0	0	0	0	0	0	0	0	2	0	0	0	2	<0.01
Freshwater drum	0	0	0	0	0	0	0	0	2	0	0	0	2	<0.01
Totals	8076	872	3086	15773	152	102	124792	88541	217800	18898	203	2481	480776	

Table 11. Estimated weight (kg) of fish impinged on the D. C. Cook Plant traveling screens in 1979. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0.07	0.0	0.22	41.54	0.77	3.23	2505.35	1353.84	390.97	43.74	1.47	96.82	4438.02	46.81
Yellow perch	43.33	15.35	62.38	27.42	3.22	0.0	53.58	241.01	1286.99	75.09	0.21	7.24	1815.82	19.15
Lake trout	88.76	67.95	0.0	0.0	10.75	0.0	0.0	106.88	44.78	331.06	63.66	148.71	862.54	9.10
Spottail shiner	58.57	4.38	9.85	96.50	0.34	0.0	22.99	68.92	111.53	91.75	0.66	1.33	466.83	4.92
White sucker	81.46	63.43	84.51	36.40	7.09	17.90	3.06	26.36	0.0	0.32	0.0	0.0	320.54	3.38
Longnose sucker	25.17	18.56	85.69	38.41	16.04	0.0	19.39	15.47	5.28	46.87	5.05	0.0	275.93	2.91
Burbot	99.50	33.48	69.16	22.53	16.83	0.0	5.61	0.52	1.11	3.25	1.92	0.0	253.92	2.68
Rainbow smelt	4.02	0.60	9.81	20.09	0.14	0.0	22.31	55.16	103.88	13.42	0.15	0.17	229.75	2.42
Chinook salmon	1.11	2.44	196.43	2.96	0.0	0.0	0.08	0.60	0.41	0.0	0.0	0.0	204.04	2.15
Trout-perch	4.00	0.67	0.52	2.81	0.03	0.0	17.67	33.84	24.84	44.92	0.55	0.65	130.52	1.38
Coho salmon	5.69	0.0	55.27	39.63	8.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	108.65	1.15
Gizzard shad	19.86	2.47	1.86	0.0	0.0	0.0	0.0	10.34	3.42	56.67	0.02	5.44	100.08	1.06
Common carp	0.0	0.0	34.52	0.0	35.66	0.0	0.0	0.12	0.0	0.0	0.0	0.0	70.30	0.74
Channel catfish	6.15	7.35	25.68	2.21	0.0	0.0	0.0	0.0	4.31	0.0	0.0	0.0	45.71	0.48
Brown trout	5.78	1.90	15.08	12.80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.56	0.38
Silver redhorse	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.42	0.0	0.0	25.42	0.27
Rainbow trout	0.0	0.0	12.75	9.59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.33	0.24
Slimy sculpin	1.55	0.45	2.05	13.90	0.19	0.0	0.70	0.65	0.10	0.28	0.0	0.53	20.39	0.22
Bloater	0.16	0.0	0.01	0.0	0.0	0.0	18.04	0.42	0.48	1.00	0.02	0.02	20.16	0.21
Shorthead redhorse	9.39	4.18	3.95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.53	0.18
Mottled sculpin	1.82	0.24	0.15	0.0	0.0	0.0	0.27	1.90	0.13	0.49	0.03	0.21	5.23	0.06
Lake whitefish	2.40	0.0	2.23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.63	0.05
Smallmouth bass	0.0	0.0	1.68	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.68	0.02
Freshwater drum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.34	0.0	0.0	0.0	1.34	0.01
Goldfish	0.0	0.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.91	0.01
Sea lamprey	0.0	0.0	0.82	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.82	0.01
Rock bass	0.0	0.0	0.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.57	0.01
White crappie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.26	0.0	0.0	0.0	0.26	<0.01
Black crappie	0.25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.25	<0.01
Ninespine stickleback	0.03	0.0	0.01	0.14	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.19	<0.01
Brown bullhead	0.0	0.0	0.0	0.13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.13	<0.01
Johnny darter	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.09	0.02	0.0	0.0	0.0	0.12	<0.01
Lake chubsucker	0.0	0.0	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	<0.01
Largemouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	0.0	0.0	0.09	<0.01
Central mudminnow	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	<0.01
Black bullhead	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	<0.01
Totals	459.08	224.37	675.27	367.16	99.13	21.13	2669.07	1916.13	1979.84	734.37	73.72	261.14	9480.40	

Table 12. Estimated number of fish impinged on the D. C. Cook Plant traveling screens in 1980. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	158	3	47	925156	527230	238227	43248	67885	7902	3749	276	1609	1815490	78.67
Yellow perch	1145	1181	889	784	87	14219	2795	9705	85087	48797	44	5529	170262	7.38
Rainbow smelt	149	152	814	6839	8526	117485	320	6912	6155	651	11	1071	149085	6.46
Spottail shiner	58	459	1854	10861	1692	14276	517	1185	61516	8286	33	5272	106009	4.59
Trout-perch	17	45	75	1433	1157	8565	166	2012	8753	7845	55	940	31063	1.35
Bloater	0	0	0	0	0	17825	4	4	3146	353	0	116	21448	0.93
Slimy sculpin	174	97	711	3299	3111	398	4	90	30	44	11	402	8371	0.36
Burbot	33	38	28	29	39	613	219	106	76	37	11	19	1248	0.05
Mottled sculpin	41	3	38	188	462	34	0	35	76	122	11	68	1078	0.05
Chinook salmon	8	0	14	5	0	804	0	4	30	0	0	10	875	0.04
Gizzard shad	0	3	42	0	0	0	0	0	15	61	44	504	669	0.03
Longnose sucker	8	21	24	11	44	318	0	8	46	0	0	10	490	0.02
Ninespine stickleback	0	0	9	2	248	165	0	0	0	0	0	5	429	0.02
Lake trout	33	21	0	2	34	43	0	8	61	27	33	58	320	0.01
White sucker	8	7	19	47	0	11	0	0	61	10	0	10	173	0.01
Brown trout	0	0	5	0	0	0	0	8	0	0	0	107	120	0.01
Johnny darter	8	0	0	0	10	9	0	16	61	3	0	0	107	<0.01
Channel catfish	8	0	9	38	0	0	0	8	0	0	0	24	87	<0.01
Coho salmon	0	21	28	4	5	0	0	0	0	0	0	5	63	<0.01
Common carp	0	0	9	0	0	0	0	0	0	24	0	0	33	<0.01
Flathead catfish	0	0	0	0	0	0	0	0	15	0	11	5	31	<0.01
Deepwater sculpin	0	0	9	0	5	0	0	8	0	0	0	5	27	<0.01
Central mudminnow	0	0	5	0	0	0	0	0	0	0	0	19	24	<0.01
Rainbow trout	0	3	9	0	0	0	0	0	0	3	0	5	20	<0.01
Smallmouth bass	0	0	0	0	0	0	0	0	0	0	0	15	15	<0.01
Lake whitefish	0	0	0	0	0	0	0	0	15	0	0	0	15	<0.01
Lake chub	0	0	0	2	0	0	0	0	0	0	11	0	13	<0.01
Bluegill	0	0	0	0	0	2	0	0	0	0	0	10	12	<0.01
Stonecat	0	0	0	0	0	0	0	0	0	0	11	0	11	<0.01
Sea lamprey	0	0	9	0	0	0	0	0	0	0	0	0	9	<0.01
Black bullhead	0	0	0	4	5	0	0	0	0	0	0	0	9	<0.01
Lake sturgeon	8	0	0	0	0	0	0	0	0	0	0	0	8	<0.01
Black crappie	0	0	0	2	0	0	0	4	0	0	0	0	6	<0.01
Green sunfish	0	0	0	0	0	2	0	4	0	0	0	0	6	<0.01
White crappie	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Longnose dace	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Largemouth bass	0	0	0	0	0	0	0	0	0	0	0	5	5	<0.01
Freshwater drum	0	0	0	0	0	0	0	4	0	0	0	0	4	<0.01
Goldfish	0	0	0	0	0	0	0	4	0	0	0	0	4	<0.01
Rock bass	0	3	0	0	0	0	0	0	0	0	0	0	3	<0.01
Warmouth	0	0	0	0	0	2	0	0	0	0	0	0	2	<0.01
Totals	1856	2057	4647	948706	542655	412998	47273	88010	173045	70012	562	15833	2307654	

Table 13. Estimated weight (kg) of fish impinged on the D. C. Cook Plant traveling screens in 1980. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	7.61	0.14	2.12	39007.29	18804.81	1238.82	1220.51	1461.82	134.25	42.76	11.12	41.15	61972.38	87.03
Yellow perch	7.23	28.36	86.51	62.00	6.29	897.54	815.34	338.02	1563.74	547.28	0.42	77.35	4430.11	6.22
Spottail shiner	0.44	5.73	24.33	123.35	19.20	103.36	4.06	7.59	551.90	66.27	0.36	53.94	960.53	1.35
Lake trout	109.28	71.83	0.0	7.06	93.88	12.68	0.0	31.03	202.88	95.60	87.87	201.15	913.26	1.28
Rainbow smelt	1.10	3.65	19.88	73.34	49.75	432.65	3.41	17.68	66.73	9.32	0.23	10.76	688.50	0.97
Longnose sucker	12.86	27.13	39.70	19.32	76.20	411.56	0.0	0.06	25.15	0.0	0.0	12.73	624.71	0.88
Burbot	2.19	8.52	2.06	3.28	22.22	241.51	212.33	35.09	3.50	7.35	8.63	9.09	555.76	0.78
Trout-perch	0.13	0.52	0.85	8.14	15.99	68.39	2.18	8.30	75.97	98.79	1.19	13.12	293.58	0.41
Chinook salmon	9.54	0.0	1.72	10.52	0.0	3.61	0.0	0.03	105.48	0.0	0.0	7.85	138.75	0.19
Gizzard shad	0.0	0.05	7.00	0.0	0.0	0.0	0.0	0.0	0.15	12.94	0.97	113.78	134.89	0.19
Bloater	0.0	0.0	0.0	0.0	0.0	102.77	0.19	0.06	8.75	0.94	0.0	0.52	113.24	0.16
White sucker	8.28	6.98	29.89	5.83	0.0	7.30	0.0	0.0	22.29	13.17	0.0	12.09	105.83	0.15
Coho salmon	0.0	20.28	27.58	2.89	3.00	0.0	0.0	0.0	0.0	0.0	0.0	3.54	57.29	0.08
Slimy sculpin	1.93	1.07	6.25	17.63	15.17	2.02	0.07	0.51	0.11	0.26	0.08	4.23	49.33	0.07
Brown trout	0.0	0.0	0.26	0.0	0.0	0.0	0.0	32.17	0.0	0.0	0.0	10.94	43.37	0.06
Lake sturgeon	38.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.57	0.05
Common carp	0.0	0.0	36.00	0.0	0.0	0.0	0.0	0.0	0.0	0.20	0.0	0.0	36.20	0.05
Rainbow trout	0.0	0.23	1.70	0.0	0.0	0.0	0.0	0.0	0.0	12.81	0.0	0.38	15.11	0.02
Mottled sculpin	0.45	0.07	0.39	1.96	6.93	0.31	0.0	0.21	0.75	0.87	0.19	0.83	12.95	0.02
Channel catfish	0.03	0.0	0.31	4.59	0.0	0.0	0.0	1.70	0.0	0.0	0.0	0.22	6.85	0.01
Lake whitefish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.13	0.0	0.0	0.0	4.13	0.01
Freshwater drum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.68	0.0	0.0	0.0	0.0	3.68	0.01
Sea lamprey	0.0	0.0	2.52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.52	<0.01
Ninespine stickleback	0.0	0.0	0.03	0.00	0.98	0.45	0.0	0.0	0.0	0.0	0.0	0.02	1.48	<0.01
Smallmouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.32	1.32	<0.01
Lake chub	0.0	0.0	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.83	0.0	0.90	<0.01
Stonecat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.75	0.0	0.75	<0.01
Black bullhead	0.0	0.0	0.0	0.32	0.27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.59	<0.01
Largemouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.44	0.44	<0.01
Deepwater sculpin	0.0	0.0	0.07	0.0	0.14	0.0	0.0	0.10	0.0	0.0	0.0	0.04	0.35	<0.01
Rock bass	0.0	0.32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.32	<0.01
Black crappie	0.0	0.0	0.0	0.19	0.0	0.0	0.0	0.12	0.0	0.0	0.0	0.0	0.31	<0.01
Johnny darter	0.03	0.0	0.0	0.0	0.03	0.02	0.0	0.03	0.14	0.01	0.0	0.0	0.26	<0.01
Central mudminnow	0.0	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.13	0.22	<0.01
Flathead catfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.0	0.06	0.02	0.18	<0.01
Longnose dace	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	0.09	<0.01
Warmouth	0.0	0.0	0.0	0.0	0.0	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.07	<0.01
Bluegill	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.0	0.0	0.02	0.05	<0.01
Green sunfish	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.01	0.0	0.0	0.0	0.0	0.02	<0.01
Goldfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.02	<0.01
White crappie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	<0.01
Totals	199.68	174.86	289.26	39347.77	19114.84	3523.10	2258.09	1938.23	2766.04	908.57	112.71	575.78	71208.81	

Table 14. Estimated number of fish impinged on the D. C. Cook Plant traveling screens in 1981. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	39	0	39	37157	543414	606466	186627	17635	1182	2086	18965	2211	1415821	69.16
Yellow perch	13149	323	167	27	4306	340156	4546	2683	934	1370	14061	10261	391983	19.15
Rainbow smelt	11419	645	34	12111	70057	778	11862	846	68	322	958	3737	112837	5.51
Spottail shiner	18629	1135	1561	381	34299	13016	1541	984	2175	1448	4141	6950	86260	4.21
Trout-perch	553	22	25	274	3310	12937	600	364	808	2259	358	2201	23711	1.16
Slimy sculpin	421	124	266	1335	2674	361	18	88	0	10	305	1372	6974	0.34
Bloater	133	0	5	0	277	132	1349	100	68	190	370	520	3144	0.15
Gizzard shad	327	43	34	0	0	0	0	0	14	54	278	932	1682	0.08
Mottled sculpin	55	5	10	27	595	334	48	100	41	44	49	56	1364	0.07
Burbot	101	91	79	33	69	129	60	169	45	41	26	33	876	0.04
Johnny darter	0	0	0	0	219	446	12	0	5	0	0	0	682	0.03
Lake trout	31	16	0	0	116	18	6	0	0	14	190	126	517	0.03
Longnose sucker	125	22	20	0	12	38	6	13	14	3	4	9	266	0.01
Channel catfish	55	22	20	0	38	0	0	0	0	3	4	33	175	0.01
Brown trout	109	5	15	0	9	0	0	19	0	0	0	9	166	0.01
White sucker	23	27	10	2	6	12	0	0	0	34	22	5	141	0.01
Ninespine stickleback	16	0	0	0	81	3	6	0	0	0	0	5	111	0.01
Deepwater sculpin	16	5	0	0	3	0	0	0	0	0	9	47	80	<0.01
Bluegill	0	0	0	2	40	3	0	0	0	0	0	28	73	<0.01
Coho salmon	16	5	0	0	0	0	0	0	0	0	0	23	44	<0.01
Central mudminnow	8	0	0	0	35	0	0	0	0	0	0	0	43	<0.01
Round whitefish	8	0	0	0	0	0	0	0	0	3	9	19	39	<0.01
Rainbow trout	23	5	0	0	3	0	0	6	0	0	0	0	37	<0.01
Black bullhead	0	0	0	0	9	3	0	13	5	0	0	5	35	<0.01
Chinook salmon	8	0	5	0	0	0	0	0	0	0	4	5	22	<0.01
White crappie	8	0	5	0	0	0	0	0	0	0	0	5	18	<0.01
Common carp	0	0	0	0	0	0	6	0	0	3	4	5	18	<0.01
Northern pike	8	0	0	0	0	0	0	0	0	0	4	5	17	<0.01
Rock bass	0	0	0	0	6	0	0	0	0	3	0	5	14	<0.01
Green sunfish	0	0	0	0	0	0	6	0	0	3	0	5	14	<0.01
Shorthead redhorse	8	0	0	0	0	0	6	0	0	0	0	0	14	<0.01
Longnose dace	8	0	0	0	0	0	0	0	0	0	0	0	8	<0.01
Sea lamprey	8	0	0	0	0	0	0	0	0	0	0	0	8	<0.01
Smallmouth bass	0	0	0	0	0	0	0	0	0	3	0	5	8	<0.01
Brown bullhead	0	0	0	2	0	0	0	0	0	0	0	5	7	<0.01
Lake whitefish	0	0	0	2	0	0	0	0	0	0	0	5	7	<0.01
Pumpkinseed	0	0	0	0	0	0	0	0	5	0	0	0	5	<0.01
Black crappie	0	0	5	0	0	0	0	0	0	0	0	0	5	<0.01
Yellow bullhead	0	0	0	0	0	0	0	0	0	3	0	0	3	<0.01
Freshwater drum	0	0	0	0	0	0	0	0	0	3	0	0	3	<0.01
Spotted sucker	0	0	0	0	3	0	0	0	0	0	0	0	3	<0.01
Totals	45304	2495	2300	51353	659581	974832	206699	23020	5364	7899	39761	28627	2047235	

Table 15. Estimated weight (kg) of fish impinged on the D. C. Cook Plant traveling screens in 1981. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0.42	0.0	1.76	842.30	4575.17	2717.56	1413.04	414.55	12.81	48.37	39.36	6.43	10071.75	57.90
Yellow perch	145.69	11.04	22.21	3.05	29.52	2198.68	176.59	111.74	32.59	76.30	281.92	163.51	3252.85	18.70
Lake trout	94.98	39.21	0.0	0.0	22.82	11.38	0.09	0.0	0.0	51.21	672.72	402.56	1294.97	7.44
Spottail shiner	213.59	14.90	21.76	4.27	278.39	88.10	14.07	8.82	22.41	17.15	50.70	82.65	816.82	4.70
Longnose sucker	207.67	26.99	31.99	0.0	19.06	51.46	8.40	13.04	15.87	4.75	5.47	15.57	400.28	2.30
Burbot	34.63	55.06	33.56	12.26	27.84	37.14	20.79	48.98	10.27	7.07	8.31	15.78	311.71	1.79
Rainbow smelt	29.84	9.16	1.09	33.46	149.24	1.58	23.99	2.61	0.74	3.55	12.03	30.40	297.68	1.71
Gizzard shad	114.40	17.81	11.25	0.0	0.0	0.0	0.0	0.0	14.86	9.08	26.66	49.19	243.25	1.40
Trout-perch	6.34	0.28	0.34	2.87	36.64	59.49	4.99	3.42	9.72	31.62	5.73	32.71	194.16	1.12
White sucker	46.14	9.72	1.59	4.46	4.84	9.42	0.0	0.0	0.0	21.20	15.92	10.77	124.06	0.71
Brown trout	26.17	0.41	9.50	0.0	12.40	0.0	0.0	60.97	0.0	0.0	0.0	1.09	110.54	0.64
Slimy sculpin	4.45	1.43	2.72	8.37	14.77	1.31	0.07	0.46	0.0	0.12	3.36	15.05	52.12	0.30
Coho salmon	9.92	3.34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.92	35.18	0.20
Channel catfish	12.01	0.55	3.07	0.0	0.09	0.0	0.0	0.0	0.0	0.01	4.30	11.97	32.01	0.18
Common carp	0.0	0.0	0.0	0.0	0.0	0.0	29.08	0.0	0.0	0.14	0.85	0.16	30.24	0.17
Bloater	0.67	0.0	0.02	0.0	3.06	1.32	15.40	0.70	0.36	1.30	1.97	2.67	27.49	0.16
Rainbow trout	3.05	3.60	0.0	0.0	2.15	0.0	0.0	10.81	0.0	0.0	0.0	0.0	19.62	0.11
Round whitefish	3.93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.24	1.64	12.88	18.70	0.11
Chinook salmon	7.41	0.0	9.60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.46	0.05	18.53	0.11
Mottled sculpin	0.68	0.09	0.11	0.37	3.39	2.65	0.44	0.93	0.50	0.50	0.41	0.63	10.71	0.06
Shorthead redhorse	2.46	0.0	0.0	0.0	0.0	0.0	3.55	0.0	0.0	0.0	0.0	0.0	6.02	0.03
Bluegill	0.0	0.0	0.0	0.05	5.21	0.01	0.0	0.0	0.0	0.0	0.0	0.38	5.65	0.03
Lake whitefish	0.0	0.0	0.0	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.92	5.00	0.03
Smallmouth bass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.56	0.0	0.09	3.65	0.02
Northern pike	1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.27	0.14	2.41	0.01
Sea lamprey	1.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.91	0.01
Johnny darter	0.0	0.0	0.0	0.0	0.52	0.70	0.02	0.0	0.01	0.0	0.0	0.0	1.25	0.01
Deepwater sculpin	0.21	0.06	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.11	0.73	1.13	0.01
Black bullhead	0.0	0.0	0.0	0.0	0.30	0.02	0.0	0.38	0.11	0.0	0.0	0.22	1.04	0.01
Rock bass	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.80	0.0	0.06	0.88	0.01
Brown bullhead	0.0	0.0	0.0	0.54	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.19	0.73	<0.01
White crappie	0.02	0.0	0.51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	0.63	<0.01
Yellow bullhead	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.46	0.0	0.0	0.46	<0.01
Central mudminnow	0.09	0.0	0.0	0.0	0.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.33	<0.01
Pumpkinseed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.31	0.0	0.0	0.0	0.31	<0.01
Ninespine stickleback	0.04	0.0	0.0	0.0	0.16	0.01	0.02	0.0	0.0	0.0	0.0	0.01	0.25	<0.01
Freshwater drum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.22	0.0	0.0	0.22	<0.01
Black crappie	0.0	0.0	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.15	<0.01
Green sunfish	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.0	0.06	0.0	0.06	0.15	<0.01
Longnose dace	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.10	<0.01
Spotted sucker	0.0	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	<0.01
Totals	967.84	193.66	151.27	912.09	5185.87	5180.80	1710.58	677.41	120.56	277.71	1134.22	882.89	17394.88	

Table 16. Estimated number of fish impinged on the D. C. Cook Plant traveling screens in 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	0	70	86310	102468	535948	85611	1391	55	608	446	144	813051	88.98
Yellow perch	2193	531	399	1086	679	6425	2900	1077	523	494	20063	2441	38811	4.25
Spottail shiner	630	149	831	27023	865	3039	562	58	89	463	94	39	33842	3.70
Rainbow smelt	46	16	18	12672	326	397	100	0	7	240	24	17	13863	1.52
Slimy sculpin	348	12	95	4308	473	566	9	0	0	0	3	6	5820	0.64
Trout-perch	88	34	28	680	124	705	88	36	117	82	10	6	1998	0.22
Gizzard shad	185	0	0	26	0	20	0	4	48	1062	547	33	1925	0.21
Burbot	51	37	49	44	178	328	100	54	76	73	17	11	1018	0.11
Longnose sucker	28	0	4	125	79	338	31	7	0	14	3	0	629	0.07
White sucker	51	6	11	55	110	288	29	4	0	27	3	0	584	0.06
Coho salmon	14	0	4	376	48	20	68	0	0	0	0	0	530	0.06
Mottled sculpin	74	0	7	169	17	89	9	0	0	5	3	0	373	0.04
Lake trout	60	6	14	55	31	50	6	0	0	23	80	17	342	0.04
Bloater	9	0	0	0	10	40	26	0	0	77	28	22	212	0.02
Brown trout	9	0	0	58	7	79	6	4	0	0	7	6	176	0.02
Channel catfish	37	3	18	18	7	0	0	4	0	0	0	0	87	0.01
Ninespine stickleback	0	0	0	44	7	20	0	0	0	0	0	0	71	0.01
Black bullhead	5	0	7	41	0	10	0	0	0	5	0	0	68	0.01
Central mudminnow	0	0	11	55	0	0	0	0	0	0	0	0	66	0.01
Bluegill	5	0	0	0	0	20	0	0	0	5	7	0	37	<0.01
Deepwater sculpin	0	0	0	3	0	0	0	0	0	5	14	11	33	<0.01
Lake chub	0	0	0	12	0	20	0	0	0	0	0	0	32	<0.01
Sea lamprey	0	0	0	0	0	30	0	0	0	0	0	0	30	<0.01
Rainbow trout	5	0	0	3	0	0	9	0	7	0	0	0	24	<0.01
Chinook salmon	5	0	0	12	3	0	3	0	0	0	0	0	23	<0.01
Johnny darter	0	0	0	0	3	10	0	0	0	0	0	0	13	<0.01
Common carp	0	3	0	9	0	0	0	0	0	0	0	0	12	<0.01
Golden shiner	0	0	0	3	0	0	6	0	0	0	0	0	9	<0.01
Pumpkinseed	0	0	0	9	0	0	0	0	0	0	0	0	9	<0.01
Black crappie	0	0	0	0	0	0	0	0	0	0	3	6	9	<0.01
Freshwater drum	5	0	0	0	0	0	0	0	0	0	3	0	8	<0.01
Longnose dace	0	0	0	0	0	0	0	0	0	5	3	0	8	<0.01
Lake whitefish	5	0	0	3	0	0	0	0	0	0	0	0	8	<0.01
Northern pike	0	0	4	3	0	0	0	0	0	0	0	0	7	<0.01
Walleye	0	0	0	0	0	0	0	0	0	0	0	6	6	<0.01
Tadpole madtom	0	0	0	3	3	0	0	0	0	0	0	0	6	<0.01
Yellow bullhead	0	0	0	3	0	0	3	0	0	0	0	0	6	<0.01
Brown bullhead	0	0	0	3	3	0	0	0	0	0	0	0	6	<0.01
Lake herring	5	0	0	0	0	0	0	0	0	0	0	0	5	<0.01
Shorthead redhorse	5	0	0	0	0	0	0	0	0	0	0	0	5	<0.01
Rock bass	0	0	0	3	0	0	0	0	0	0	0	0	3	<0.01
Longnose gar	0	0	0	3	0	0	0	0	0	0	0	0	3	<0.01
Totals	3863	797	1570	133217	105441	548442	89566	2639	922	3188	21358	2765	913768	

Table 17. Estimated weight (kg) of fish impinged on the D. C. Cook Plant traveling screens in 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0.0	0.0	3.07	3808.63	2620.79	10720.43	1890.10	30.48	1.06	9.39	2.17	2.19	19088.29	75.83
Yellow perch	97.59	17.16	36.35	75.58	30.53	265.20	186.02	50.98	23.39	19.94	842.58	115.94	1761.28	7.00
Lake trout	133.24	33.98	41.85	30.95	92.84	166.13	7.20	0.0	0.0	70.25	251.87	72.93	901.24	3.58
Longnose sucker	46.90	0.0	6.66	163.48	92.28	351.81	18.47	8.49	0.0	29.38	2.35	0.0	719.81	2.86
Coho salmon	4.79	0.0	3.25	362.82	39.25	9.34	49.23	0.0	0.0	0.0	0.0	0.0	468.67	1.86
White sucker	51.93	1.63	8.65	33.44	84.26	211.03	23.14	0.02	0.0	5.40	0.16	0.0	419.65	1.67
Spottail shiner	8.31	2.55	13.11	333.33	10.70	33.79	5.88	0.75	1.32	5.86	0.99	0.55	417.14	1.66
Brown trout	5.12	0.0	0.0	120.38	13.81	233.46	13.48	11.82	0.0	0.0	6.39	6.92	411.38	1.63
Burbot	36.47	20.24	25.27	22.07	79.21	119.02	33.47	20.79	28.56	19.71	2.14	3.96	410.90	1.63
Gizzard shad	142.19	0.0	0.0	14.84	0.0	0.01	0.0	4.03	5.77	65.80	11.71	4.46	248.82	0.99
Rainbow smelt	0.73	0.19	0.40	103.15	4.08	3.61	0.53	0.0	0.15	4.56	0.40	0.29	118.11	0.47
Common carp	0.0	20.73	0.0	28.60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49.33	0.20
Slimy sculpin	3.81	0.13	1.04	31.04	2.46	2.93	0.03	0.0	0.0	0.0	0.03	0.05	41.54	0.17
Trout-perch	1.96	0.74	0.56	8.51	1.60	9.63	1.16	0.59	2.04	1.30	0.13	0.09	28.30	0.11
Chinook salmon	2.79	0.0	0.0	23.08	0.03	0.0	0.03	0.0	0.0	0.0	0.0	0.0	25.94	0.10
Channel catfish	10.85	0.05	3.46	0.81	0.16	0.0	0.0	0.84	0.0	0.0	0.0	0.0	16.17	0.06
Rainbow trout	4.98	0.0	0.0	0.70	0.0	0.0	4.43	0.0	2.67	0.0	0.0	0.0	12.79	0.05
Lake whitefish	3.32	0.0	0.0	2.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.36	0.02
Lake herring	4.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.91	0.02
Mottled sculpin	1.03	0.0	0.08	1.35	0.11	0.54	0.08	0.0	0.0	0.04	0.02	0.0	3.26	0.01
Sea lamprey	0.0	0.0	0.0	0.0	0.0	3.14	0.0	0.0	0.0	0.0	0.0	0.0	3.14	0.01
Northern pike	0.0	0.0	1.23	1.26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.48	0.01
Black bullhead	0.32	0.0	0.80	0.99	0.0	0.19	0.0	0.0	0.0	0.01	0.0	0.0	2.31	0.01
Yellow bullhead	0.0	0.0	0.0	0.52	0.0	0.0	1.37	0.0	0.0	0.0	0.0	0.0	1.89	0.01
Lake chub	0.0	0.0	0.0	0.75	0.0	0.93	0.0	0.0	0.0	0.0	0.0	0.0	1.68	0.01
Freshwater drum	0.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.56	0.0	1.64	0.01
Bloater	0.06	0.0	0.0	0.0	0.06	0.40	0.30	0.0	0.0	0.51	0.11	0.08	1.54	0.01
Black crappie	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.64	0.52	1.16	<0.01
Bluegill	0.04	0.0	0.0	0.0	0.0	0.20	0.0	0.0	0.0	0.63	0.17	0.0	1.03	<0.01
Shorthead redhorse	0.52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.52	<0.01
Longnose gar	0.0	0.0	0.0	0.52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.52	<0.01
Deepwater sculpin	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.04	0.24	0.19	0.50	<0.01
Pumpkinseed	0.0	0.0	0.0	0.43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.43	<0.01
Central mudminnow	0.0	0.0	0.11	0.28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.39	<0.01
Brown bullhead	0.0	0.0	0.0	0.20	0.18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.38	<0.01
Ninespine stickleback	0.0	0.0	0.0	0.21	0.01	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.37	<0.01
Rock bass	0.0	0.0	0.0	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	<0.01
Longnose dace	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.02	0.0	0.05	<0.01
Walleye	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	0.05	<0.01
Tadpole madtom	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02	<0.01
Golden shiner	0.0	0.0	0.0	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.02	<0.01
Johnny darter	0.0	0.0	0.0	0.0	0.01	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.01	<0.01
Totals	561.94	97.40	145.89	5170.06	3072.39	12131.90	2234.94	128.79	64.95	232.85	1123.71	208.24	25173.05	

In general, species composition of impinged fish reflected fish abundance in the nearshore area (<10-m depth) tempered by the unique vulnerability of certain species to the impingement process. Differences in species composition among years could usually be attributed to fluctuations in year-class strength among the most abundant species, or seasonal differences in periods of maximum or minimum pumping levels.

Because both units were operating during 1978-1982, these years should be considered separately from 1975 to 1977 when only one unit was operating. An overview of the data (Fig. 1) shows that during one-unit operation, 1975-1977, impingement of alewives was around 100,000 fish (Tables 2, 4, 6), and volume of cooling water pumped through the plant was also consistent, around 1.2×10^9 m^3/yr (Table 18). During these years, alewife populations in the lake fluctuated according to our index data, from about 42,000 fish in standard series catches in 1975, to 137,000 in 1976, and back to 56,000 in 1977 (Tables 19-28). Thus, it appeared that although alewife populations varied a great deal in Lake Michigan, these variations did not increase impingement substantially during 1976 when alewife abundance was highest of the 3 years in Lake Michigan.

All variables changed in the next 5 years of operation (1978-1982) as Unit 2 doubled plant pumping rates from around 1.2×10^9 m^3/yr to 2.3-2.8 $\times 10^9$ m^3/yr (Table 18). Alewife populations in the lake exhibited a catastrophic decline starting in 1980 (Tables 21-28), while impingement rates increased dramatically in the 1980s (Tables 2-17). Sorting out possible causal mechanisms is difficult because of the many varying factors.
For example, even though total volume of cooling water increased twofold from 1977 to 1978, impingement losses did not rise proportionally. This seeming

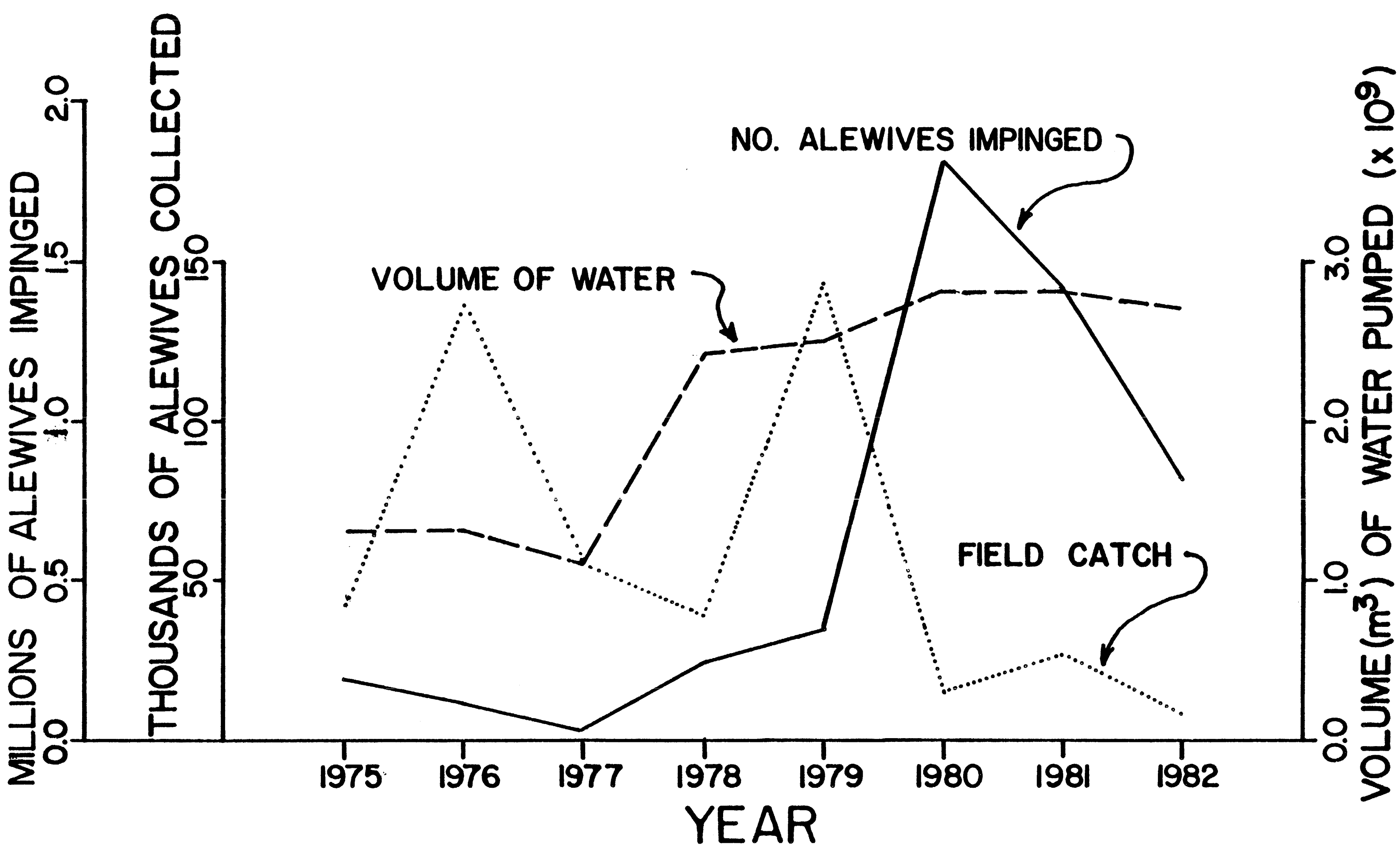

Figure 1. A plot of annual impingement losses of alewife, volume of water pumped by the plant, and field abundance of alewife at the D. C. Cook Plant, 1975-1982. Unit 1 went on line in 1975, Unit 2 in 1978.

Table 18. Monthly water volume (in millions of cubic meters) pumped through the condenser circulating water system of the Cook Plant, southeastern Lake Michigan from 1975 to 1982. Unit 1 was operational since January 1975, Unit 2 since February 1978.

Month	1975	1976	1977	1978	1979	1980	1981	1982
January	64.9	85.7	24.9	114.4	273.2	142.5	270.8	275.7
February	75.6	88.5	54.5	121.6	275.2	280.9	282.5	177.8
March	117.7	103.6	118.7	207.1	281.9	314.4	213.6	195.5
April	121.0	76.2	114.5	115.9	173.7	304.5	128.8	291.8
May	125.8	86.0	97.4	90.4	100.5	318.4	196.5	308.6
June	122.8	122.7	93.5	194.4	33.3	167.6	165.0	309.2
July	81.7	120.5	103.6	224.5	227.7	101.0	142.4	190.3
August	128.7	130.5	123.3	249.6	324.6	297.0	290.6	87.4
September	125.2	109.0	97.7	277.6	314.3	303.1	305.0	206.4
October	132.2	137.9	112.4	298.8	245.9	247.7	182.4	296.1
November	90.6	126.2	76.3	202.8	107.3	125.8	265.3	265.2
December	111.6	105.1	120.9	272.5	118.0	227.1	310.2	145.4
Annual total	1,298	1,292	1,138	2,370	2,476	2,830	2,753	2,749

Table 19. Number of fish caught by standard series trawling, gillnetting, and seining in D. C. Cook Plant study areas, southeastern Lake Michigan, 1973. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	0	1869	10286	3207	6791	13204	79934	765	32389	5	0	148450	76.56
Spottail shiner	ND	17	439	2687	3374	7416	1819	2510	768	1431	121	1	20583	10.62
Rainbow smelt	ND	4	119	3926	823	957	294	8394	1425	338	14	0	16294	8.40
Yellow perch	ND	6	35	15	41	1458	611	909	243	395	22	0	3735	1.93
Trout-perch	ND	0	2	47	156	1615	703	515	160	339	21	0	3558	1.83
Johnny darter	ND	0	0	13	47	58	17	31	11	30	0	0	207	0.11
White sucker	ND	1	7	7	14	26	22	30	41	26	0	0	174	0.09
Lake trout	ND	0	2	1	2	2	6	19	49	27	54	0	162	0.08
Bloater	ND	0	0	0	2	26	42	35	1	20	0	0	126	0.06
Rainbow trout	ND	1	1	15	30	13	6	11	1	3	5	0	86	0.04
Slimy sculpin	ND	0	0	44	14	3	0	6	4	7	1	0	79	0.04
Brown trout	ND	1	4	2	6	33	18	4	3	7	0	0	78	0.04
Longnose sucker	ND	1	4	9	15	14	27	1	1	1	0	0	73	0.04
Emerald shiner	ND	1	2	1	6	1	2	11	15	8	2	0	49	0.03
Longnose dace	ND	2	0	2	4	3	3	4	22	0	1	0	41	0.02
Northern pike	ND	0	0	0	0	2	0	1	8	10	9	0	30	0.02
Chinook salmon	ND	0	1	2	5	12	2	2	3	2	0	0	29	0.01
Common carp	ND	0	0	2	2	14	1	2	0	6	0	0	27	0.01
Coho salmon	ND	0	5	3	9	1	0	0	3	2	0	0	23	0.01
Gizzard shad	ND	0	0	0	0	0	0	0	0	1	22	0	23	0.01
Ninespine stickleback	ND	0	1	1	12	5	0	0	0	0	0	0	19	0.01
Mottled sculpin	ND	0	0	9	3	2	0	0	0	2	0	0	16	0.01
Bluegill	ND	0	0	0	1	3	0	1	0	0	5	0	10	0.01
Channel catfish	ND	1	0	0	0	1	0	2	0	2	4	0	10	0.01
Burbot	ND	0	0	4	0	2	0	0	0	0	0	0	6	<0.01
Golden shiner	ND	0	0	2	0	0	0	0	0	0	0	0	2	<0.01
Lake whitefish	ND	0	0	0	1	1	0	0	0	0	0	0	2	<0.01
Rock bass	ND	0	0	0	0	1	0	0	0	0	1	0	2	<0.01
Black bullhead	ND	0	0	1	0	0	1	0	0	0	0	0	2	<0.01
Fathead minnow	ND	0	0	0	1	0	1	0	0	0	0	0	2	<0.01
Largemouth bass	ND	0	0	1	0	0	0	0	0	0	0	0	1	<0.01
Totals	ND	35	2491	17080	7775	18460	16779	92422	3523	35046	287	1	193899	

Table 20. Number of fish caught by standard series trawling, gillnetting, and seining in D. C. Cook Plant study areas, southeastern Lake Michigan, 1974. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	ND	282	4829	13911	3788	4662	36669	8257	2977	724	0	76099	66.71
Spottail shiner	1	ND	167	313	4111	6942	5884	6047	414	476	36	22	24413	21.40
Rainbow smelt	0	ND	55	701	794	59	385	3304	93	345	13	5	5754	5.04
Yellow perch	1	ND	14	35	14	156	2581	1182	453	9	75	16	4536	3.98
Trout-perch	0	ND	0	10	145	55	928	128	106	187	17	2	1578	1.38
Johnny darter	0	ND	0	5	93	86	60	6	7	22	14	0	293	0.26
Slimy sculpin	0	ND	2	155	19	15	14	28	2	18	19	0	272	0.24
Bloater	0	ND	0	0	0	3	199	7	1	15	0	0	225	0.20
Coho salmon	0	ND	8	7	68	13	0	26	0	0	25	0	147	0.13
White sucker	2	ND	2	3	16	19	29	13	16	13	5	8	126	0.11
Lake trout	0	ND	1	1	17	9	0	0	0	12	85	0	125	0.11
Longnose sucker	1	ND	2	4	26	11	39	2	3	3	6	2	99	0.09
Gizzard shad	0	ND	5	4	44	1	0	1	20	9	0	0	84	0.07
Brown trout	0	ND	3	5	14	13	6	5	2	1	2	0	51	0.04
Chinook salmon	0	ND	0	4	9	3	8	6	13	0	3	1	47	0.04
Bluegill	0	ND	1	0	40	5	0	0	0	0	0	0	46	0.04
Longnose dace	0	ND	2	1	3	8	2	1	0	20	6	0	43	0.04
Common carp	0	ND	0	2	7	0	1	9	5	3	0	0	27	0.02
Ninespine stickleback	0	ND	0	1	15	4	3	1	0	0	0	0	24	0.02
Channel catfish	0	ND	0	1	0	1	8	0	5	1	1	0	17	0.01
Northern pike	1	ND	3	3	1	2	0	1	0	5	0	0	16	0.01
Burbot	0	ND	1	1	2	1	0	0	0	0	0	10	15	0.01
Emerald shiner	0	ND	2	1	1	3	0	0	0	6	0	0	13	0.01
Rainbow trout	0	ND	5	2	0	0	0	0	0	0	1	0	8	0.01
Green sunfish	0	ND	0	0	5	0	0	0	0	1	0	0	6	0.01
Sand shiner	0	ND	0	0	0	0	0	0	0	3	1	0	4	<0.01
Black bullhead	0	ND	0	1	1	0	0	0	0	0	0	0	2	<0.01
Bluntnose minnow	0	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Lake herring	0	ND	0	0	0	0	0	0	0	0	0	1	1	<0.01
Largemouth bass	0	ND	0	0	0	1	0	0	0	0	0	0	1	<0.01
Lake whitefish	0	ND	0	0	0	0	0	1	0	0	0	0	1	<0.01
Golden shiner	0	ND	0	0	0	0	0	1	0	0	0	0	1	<0.01
Totals	6	ND	555	6089	19356	11198	14809	47438	9397	4127	1033	67	114075	

Table 21. Number of fish caught by standard series trawling, gillnetting, and seining in D. C. Cook Plant study areas, southeastern Lake Michigan, 1975. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	0	ND	797	176	6974	2718	1096	757	7740	21270	168	42	41738	58.79
Spottail shiner	1	ND	12	103	1740	8483	3076	1583	2022	1535	428	831	19814	27.91
Yellow perch	7	ND	29	12	4	964	2143	560	281	151	103	80	4334	6.10
Rainbow smelt	3	ND	21	255	1233	1032	0	173	94	179	105	14	3109	4.38
Trout-perch	0	ND	0	14	151	221	68	114	150	108	51	28	905	1.27
Gizzard shad	0	ND	0	2	0	0	0	28	18	13	106	26	193	0.27
Johnny darter	0	ND	0	2	35	19	3	5	31	19	19	9	142	0.20
Slimy sculpin	0	ND	0	38	48	12	0	1	1	2	5	4	111	0.16
Longnose sucker	1	ND	50	3	9	22	1	2	1	2	3	0	94	0.13
White sucker	1	ND	7	3	6	37	9	0	17	2	2	5	89	0.13
Lake trout	0	ND	1	3	8	21	0	0	0	4	47	1	85	0.12
Chinook salmon	0	ND	0	3	0	18	3	5	2	20	7	1	59	0.08
Coho salmon	0	ND	6	40	1	5	0	0	0	0	2	0	54	0.08
Common carp	0	ND	0	0	1	0	14	14	17	2	2	0	50	0.07
Bloater	0	ND	0	0	2	34	0	11	1	1	0	0	49	0.07
Sand shiner	0	ND	0	0	0	0	0	0	1	1	32	0	34	0.05
Brown trout	0	ND	7	2	1	1	1	1	1	1	10	1	26	0.04
Ninespine stickleback	0	ND	0	2	10	14	0	0	0	0	0	0	26	0.04
Longnose dace	0	ND	0	0	0	1	0	2	2	7	6	0	18	0.03
Burbot	1	ND	0	0	0	0	0	0	0	1	0	13	15	0.02
Rainbow trout	0	ND	1	2	0	0	1	0	1	6	3	1	15	0.02
Channel catfish	0	ND	0	0	0	0	1	1	5	1	1	0	9	0.01
Northern pike	1	ND	0	1	0	1	0	0	0	0	3	0	6	0.01
Shorthead redhorse	0	ND	0	0	0	0	0	0	4	0	0	0	4	0.01
Lake whitefish	0	ND	0	1	0	1	0	0	0	0	0	0	2	<0.01
Logperch	0	ND	0	0	1	1	0	0	0	0	0	0	2	<0.01
Bluegill	0	ND	0	0	0	1	0	0	1	0	0	0	2	<0.01
Silver redhorse	0	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Emerald shiner	0	ND	0	1	0	0	0	0	0	0	0	0	1	<0.01
Lake herring	0	ND	0	1	0	0	0	0	0	0	0	0	1	<0.01
Pumpkinseed	0	ND	0	0	0	0	1	0	0	0	0	0	1	<0.01
Quillback	0	ND	0	0	0	1	0	0	0	0	0	0	1	<0.01
Largemouth bass	0	ND	0	0	0	1	0	0	0	0	0	0	1	<0.01
Lake sturgeon	0	ND	0	0	1	0	0	0	0	0	0	0	1	<0.01
Totals	15	ND	931	664	10225	13608	6417	3257	10390	23326	1103	1056	70992	

Table 22. Number of fish caught by standard series trawling, gillnetting, and seining in D. C. Cook Plant study areas, southeastern Lake Michigan, 1976. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	0	204	2020	7446	3862	2852	43406	74708	2225	20	ND	136743	86.77
Spottail shiner	ND	47	49	967	1708	3307	5309	581	823	1178	147	ND	14116	8.96
Yellow perch	ND	13	5	54	24	318	1242	386	422	30	4	ND	2498	1.59
Trout-perch	ND	2	1	25	118	115	1146	134	261	145	8	ND	1955	1.24
Rainbow smelt	ND	1	21	452	67	143	416	19	11	13	122	ND	1265	0.80
Johnny darter	ND	0	0	2	139	12	25	30	31	59	6	ND	304	0.19
Bloater	ND	0	0	3	2	26	76	0	0	0	0	ND	107	0.07
Brown trout	ND	6	0	2	32	18	10	1	17	4	0	ND	90	0.06
White sucker	ND	4	0	6	24	5	18	5	18	8	1	ND	89	0.06
Slimy sculpin	ND	0	0	55	12	2	0	6	2	5	3	ND	85	0.05
Gizzard shad	ND	1	0	0	0	1	1	20	20	7	1	ND	51	0.03
Longnose sucker	ND	20	3	8	4	3	2	0	0	0	0	ND	40	0.03
Sand shiner	ND	0	0	1	0	0	0	7	0	31	0	ND	39	0.02
Lake trout	ND	0	3	6	8	7	2	0	0	11	0	ND	37	0.02
Chinook salmon	ND	1	0	0	8	19	2	0	4	1	0	ND	35	0.02
Common carp	ND	0	0	0	10	2	1	14	4	1	0	ND	32	0.02
Longnose dace	ND	0	0	1	3	2	1	5	10	1	4	ND	27	0.02
Coho salmon	ND	0	0	0	19	6	0	0	0	0	0	ND	25	0.02
Rainbow trout	ND	2	0	2	2	1	1	0	4	2	0	ND	14	0.01
Channel catfish	ND	0	0	0	2	0	1	2	8	0	0	ND	13	0.01
Ninespine stickleback	ND	0	0	0	8	1	0	0	0	0	0	ND	9	0.01
Burbot	ND	1	0	2	0	0	1	0	0	2	0	ND	6	<0.01
Lake whitefish	ND	0	1	2	1	1	1	0	0	0	0	ND	6	<0.01
Silver redhorse	ND	0	0	0	0	0	3	0	0	0	0	ND	3	<0.01
Bluegill	ND	0	0	0	1	0	1	0	0	0	1	ND	3	<0.01
Quillback	ND	0	0	0	0	1	1	0	0	0	0	ND	2	<0.01
Golden shiner	ND	1	0	0	0	0	0	0	0	1	0	ND	2	<0.01
Brook silverside	ND	0	0	1	0	0	0	0	0	0	0	ND	1	<0.01
Smallmouth bass	ND	0	0	0	0	0	0	1	0	0	0	ND	1	<0.01
Largemouth bass	ND	0	0	0	0	0	0	1	0	0	0	ND	1	<0.01
Lake sturgeon	ND	0	0	0	1	0	0	0	0	0	0	ND	1	<0.01
Totals	ND	99	287	3609	9639	7852	11112	44618	76343	3724	317	ND	157600	

Table 23. Number of fish caught by standard series trawling, gillnetting, and seining in D. C. Cook Plant study areas, southeastern Lake Michigan, 1977. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	66	34	1270	1607	3507	20151	12731	3017	13596	0	55979	63.35
Spottail shiner	ND	ND	54	20	2333	2190	2363	10098	3548	1564	398	0	22568	25.54
Yellow perch	ND	ND	11	28	19	189	1301	897	470	47	416	1	3379	3.82
Trout-perch	ND	ND	1	4	193	317	1919	130	172	501	2	0	3239	3.67
Rainbow smelt	ND	ND	0	113	170	2	669	88	99	148	166	0	1455	1.65
Johnny darter	ND	ND	0	34	171	44	31	41	82	4	16	0	423	0.48
Bloater	ND	ND	0	0	0	24	40	0	7	141	15	0	227	0.26
Lake trout	ND	ND	4	10	6	6	6	0	9	27	119	0	187	0.21
White sucker	ND	ND	0	8	29	18	68	13	23	8	5	1	173	0.20
Chinook salmon	ND	ND	11	21	83	44	0	0	0	1	0	0	160	0.18
Gizzard shad	ND	ND	0	0	0	0	1	15	39	41	8	0	104	0.12
Longnose sucker	ND	ND	4	5	3	0	34	9	14	6	24	0	99	0.11
Common carp	ND	ND	0	5	30	0	5	22	20	3	7	0	92	0.10
Brown trout	ND	ND	5	9	8	13	5	0	5	1	9	6	61	0.07
Longnose dace	ND	ND	0	1	0	3	1	0	9	38	8	0	60	0.07
Slimy sculpin	ND	ND	0	15	0	0	7	1	2	0	5	0	30	0.03
Emerald shiner	ND	ND	0	0	0	2	22	0	0	3	0	0	27	0.03
Sand shiner	ND	ND	0	1	0	2	13	5	1	0	1	0	23	0.03
Coho salmon	ND	ND	3	1	0	1	0	0	1	2	4	0	12	0.01
Rainbow trout	ND	ND	0	2	1	0	1	0	6	0	2	0	12	0.01
Golden redhorse	ND	ND	0	0	0	0	0	6	3	0	0	0	9	0.01
Channel catfish	ND	ND	0	0	0	0	0	5	2	2	0	0	9	0.01
Burbot	ND	ND	1	0	0	0	0	1	0	0	0	6	8	0.01
Ninespine stickleback	ND	ND	0	0	5	0	2	0	0	0	0	0	7	0.01
Quillback	ND	ND	0	0	0	0	0	1	2	0	0	0	3	<0.01
Mottled sculpin	ND	ND	0	0	0	0	0	0	0	3	0	0	3	<0.01
Bluegill	ND	ND	0	0	0	1	0	0	1	0	0	0	2	<0.01
Lake sturgeon	ND	ND	0	0	0	0	1	1	0	0	0	0	2	<0.01
Bluntnose minnow	ND	ND	0	0	0	0	0	1	0	0	0	0	1	<0.01
Golden shiner	ND	ND	0	0	0	0	0	0	1	0	0	0	1	<0.01
Creek chub	ND	ND	0	0	0	0	1	0	0	0	0	0	1	<0.01
Rock bass	ND	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Silver redhorse	ND	ND	0	0	0	0	0	0	1	0	0	0	1	<0.01
Shorthead redhorse	ND	ND	0	0	0	0	0	0	0	0	0	1	1	<0.01
Freshwater drum	ND	ND	0	0	0	0	0	0	0	1	0	0	1	<0.01
Totals	ND	ND	160	311	4321	4463	9997	31485	17248	5559	14801	15	88360	

Table 24. Number of fish caught by standard series trawling, gillnetting, and seining in D. C. Cook Plant study areas, southeastern Lake Michigan, 1978. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	4	294	5498	641	1786	2686	27840	704	ND	39453	42.27
Spottail shiner	ND	ND	ND	108	414	6824	15913	6064	2288	4788	202	ND	36601	39.21
Rainbow smelt	ND	ND	ND	66	1840	59	1844	5446	89	109	68	ND	9521	10.20
Trout-perch	ND	ND	ND	5	64	194	610	310	254	1631	20	ND	3088	3.31
Yellow perch	ND	ND	ND	50	4	181	379	206	609	57	90	ND	1576	1.69
Bloater	ND	ND	ND	0	1	117	269	868	29	52	56	ND	1392	1.49
Johnny darter	ND	ND	ND	1	93	57	82	17	5	112	34	ND	401	0.43
Chinook salmon	ND	ND	ND	7	6	274	15	2	7	22	4	ND	337	0.36
Lake trout	ND	ND	ND	9	34	31	18	11	89	53	41	ND	286	0.31
Brown trout	ND	ND	ND	63	12	9	10	11	30	17	10	ND	162	0.17
White sucker	ND	ND	ND	1	6	9	15	9	36	31	11	ND	118	0.13
Gizzard shad	ND	ND	ND	0	0	0	0	0	12	86	8	ND	106	0.11
Longnose sucker	ND	ND	ND	14	2	2	1	7	12	8	25	ND	71	0.08
Coho salmon	ND	ND	ND	11	23	4	11	17	4	0	0	ND	70	0.07
Common carp	ND	ND	ND	0	4	0	1	2	6	18	5	ND	36	0.04
Longnose dace	ND	ND	ND	3	3	2	0	0	5	8	5	ND	26	0.03
Rainbow trout	ND	ND	ND	4	1	2	2	5	1	5	1	ND	21	0.02
Slimy sculpin	ND	ND	ND	5	6	1	1	0	0	1	0	ND	14	0.01
Sand shiner	ND	ND	ND	0	0	0	0	0	12	0	0	ND	12	0.01
Emerald shiner	ND	ND	ND	0	0	0	0	3	0	7	0	ND	10	0.01
Lake whitefish	ND	ND	ND	0	1	3	0	2	2	0	1	ND	9	0.01
Channel catfish	ND	ND	ND	0	0	0	1	0	1	2	1	ND	5	0.01
Burbot	ND	ND	ND	2	1	0	0	0	0	1	1	ND	5	0.01
Ninespine stickleback	ND	ND	ND	1	2	1	0	0	1	0	0	ND	5	0.01
Spotfin shiner	ND	ND	ND	0	0	0	0	0	2	0	0	ND	2	<0.01
Northern pike	ND	ND	ND	0	0	0	0	0	0	2	0	ND	2	<0.01
Quillback	ND	ND	ND	0	0	0	0	0	0	2	0	ND	2	<0.01
Golden shiner	ND	ND	ND	0	0	0	2	0	0	0	0	ND	2	<0.01
Silver redhorse	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Blackchin shiner	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Brook silverside	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Lake herring	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Lake sturgeon	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	<0.01
Fathead minnow	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Totals	ND	ND	ND	355	2811	13269	19815	14766	6182	34853	1288	ND	93339	

Table 25. Number of fish caught by standard series trawling, gillnetting, and seining in D. C. Cook Plant study areas, southeastern Lake Michigan, 1979. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	267	71	2248	1178	17104	66560	54605	140	ND	142173	76.34
Spottail shiner	ND	ND	ND	711	834	3475	9796	2147	8582	2075	200	ND	27820	14.94
Rainbow smelt	ND	ND	ND	788	2152	579	147	939	54	150	467	ND	5276	2.83
Yellow perch	ND	ND	ND	41	25	104	511	1031	2733	63	151	ND	4659	2.50
Bloater	ND	ND	ND	0	4	68	1979	3	497	90	347	ND	2988	1.60
Trout-perch	ND	ND	ND	41	27	152	326	376	324	461	23	ND	1730	0.93
Chinook salmon	ND	ND	ND	168	83	61	1	1	7	0	1	ND	322	0.17
Johnny darter	ND	ND	ND	20	52	53	38	1	42	20	7	ND	233	0.13
White sucker	ND	ND	ND	40	19	31	8	41	30	18	1	ND	188	0.10
Lake trout	ND	ND	ND	15	3	4	0	2	0	55	85	ND	164	0.09
Gizzard shad	ND	ND	ND	3	0	1	0	6	124	17	8	ND	159	0.09
Slimy sculpin	ND	ND	ND	89	28	7	1	0	0	1	2	ND	128	0.07
Longnose sucker	ND	ND	ND	2	35	20	5	9	20	7	0	ND	98	0.05
Common carp	ND	ND	ND	11	29	7	2	12	3	7	0	ND	71	0.04
Coho salmon	ND	ND	ND	39	26	0	0	0	0	0	0	ND	65	0.03
Brown trout	ND	ND	ND	20	10	9	11	0	1	4	5	ND	60	0.03
Rainbow trout	ND	ND	ND	3	1	1	1	1	2	2	3	ND	14	0.01
Emerald shiner	ND	ND	ND	7	1	3	0	0	0	0	1	ND	12	0.01
Silver redhorse	ND	ND	ND	0	0	0	0	1	6	3	0	ND	10	0.01
Channel catfish	ND	ND	ND	1	0	0	0	3	3	1	0	ND	8	<0.01
Ninespine stickleback	ND	ND	ND	0	1	7	0	0	0	0	0	ND	8	<0.01
Sand shiner	ND	ND	ND	0	0	0	0	0	0	7	0	ND	7	<0.01
Lake whitefish	ND	ND	ND	3	3	1	0	0	0	0	0	ND	7	<0.01
Longnose dace	ND	ND	ND	3	0	0	0	0	1	2	0	ND	6	<0.01
Mottled sculpin	ND	ND	ND	2	0	0	0	0	0	0	4	ND	6	<0.01
Burbot	ND	ND	ND	1	0	2	0	2	0	0	0	ND	5	<0.01
Shorthead redhorse	ND	ND	ND	1	0	0	1	0	0	2	0	ND	4	<0.01
Northern pike	ND	ND	ND	0	0	0	0	1	3	0	0	ND	4	<0.01
Spotfin shiner	ND	ND	ND	0	0	0	0	2	0	1	0	ND	3	<0.01
Golden redhorse	ND	ND	ND	0	0	0	0	0	3	0	0	ND	3	<0.01
Round whitefish	ND	ND	ND	1	0	0	0	0	0	1	0	ND	2	<0.01
Fathead minnow	ND	ND	ND	0	0	1	0	1	0	0	0	ND	2	<0.01
Central mudminnow	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Bluntnose minnow	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Lake chub	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Black crappie	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Green sunfish	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Bluegill	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	2279	3406	6836	14005	21683	78995	57592	1445	ND	186241	

Table 26. Number of fish caught by standard series trawling, gillnetting, and seining in D. C. Cook Plant study areas, southeastern Lake Michigan, 1980. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Spottail shiner	ND	ND	ND	157	6349	3621	7923	2699	9416	2119	555	ND	32839	40.32
Alewife	ND	ND	ND	813	4777	4228	2349	2325	1344	301	313	ND	16450	20.20
Yellow perch	ND	ND	ND	6	49	329	2020	1532	7564	1088	182	ND	12770	15.68
Rainbow smelt	ND	ND	ND	517	4676	2386	89	1345	519	2023	888	ND	12443	15.28
Trout-perch	ND	ND	ND	14	483	358	363	674	437	773	20	ND	3122	3.83
Bloater	ND	ND	ND	0	143	1064	754	20	794	68	18	ND	2861	3.51
Johnny darter	ND	ND	ND	3	64	67	4	5	23	29	3	ND	198	0.24
Chinook salmon	ND	ND	ND	2	12	141	11	3	9	1	3	ND	182	0.22
Lake trout	ND	ND	ND	2	17	9	0	11	34	16	32	ND	121	0.15
White sucker	ND	ND	ND	2	31	23	26	3	4	18	6	ND	113	0.14
Slimy sculpin	ND	ND	ND	23	19	7	0	0	2	1	3	ND	55	0.07
Gizzard shad	ND	ND	ND	0	1	9	1	2	7	19	14	ND	53	0.07
Longnose sucker	ND	ND	ND	2	14	9	3	3	8	3	5	ND	47	0.06
Brown trout	ND	ND	ND	15	6	9	0	5	1	1	3	ND	40	0.05
Longnose dace	ND	ND	ND	0	1	2	0	5	2	22	2	ND	34	0.04
Common carp	ND	ND	ND	2	3	2	3	4	4	7	3	ND	28	0.03
Rainbow trout	ND	ND	ND	3	0	0	0	0	0	9	10	ND	22	0.03
Mottled sculpin	ND	ND	ND	1	5	3	0	1	2	2	1	ND	15	0.02
Lake whitefish	ND	ND	ND	0	12	0	0	1	0	0	1	ND	14	0.02
Coho salmon	ND	ND	ND	2	6	2	0	0	3	0	0	ND	13	0.02
Sand shiner	ND	ND	ND	0	0	0	1	5	0	3	1	ND	10	0.01
Ninespine stickleback	ND	ND	ND	1	4	3	0	0	0	0	0	ND	8	0.01
Burbot	ND	ND	ND	1	0	3	0	0	2	0	1	ND	7	0.01
Black bullhead	ND	ND	ND	0	0	2	1	0	0	0	0	ND	3	<0.01
Silver redhorse	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
White crappie	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Fathead minnow	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	1567	16672	12278	13548	8644	20175	6503	2064	ND	81451	

Table 27. Number of fish caught by standard series trawling, gillnetting, and seining in D. C. Cook Plant study areas, southeastern Lake Michigan, 1981. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Alewife	ND	ND	ND	883	5448	2684	596	14986	711	1000	178	ND	26486	26.07
Yellow perch	ND	ND	ND	1183	154	6699	10485	490	1795	4404	640	ND	25850	25.44
Spottail shiner	ND	ND	ND	526	1515	15506	2486	558	367	962	711	ND	22631	22.28
Rainbow smelt	ND	ND	ND	5069	6761	592	565	4	111	272	876	ND	14250	14.03
Bloater	ND	ND	ND	1	34	1428	8140	0	35	219	55	ND	9912	9.76
Trout-perch	ND	ND	ND	31	433	202	516	60	210	102	54	ND	1608	1.58
Johnny darter	ND	ND	ND	11	81	24	10	4	6	7	8	ND	151	0.15
White sucker	ND	ND	ND	8	11	25	45	4	13	19	6	ND	131	0.13
Lake trout	ND	ND	ND	11	18	7	5	0	0	18	46	ND	105	0.10
Gizzard shad	ND	ND	ND	3	0	0	1	23	14	26	15	ND	82	0.08
Slimy sculpin	ND	ND	ND	40	14	5	3	0	0	2	10	ND	74	0.07
Longnose sucker	ND	ND	ND	11	15	32	3	2	1	2	4	ND	70	0.07
Common carp	ND	ND	ND	2	0	5	1	17	9	14	0	ND	48	0.05
Chinook salmon	ND	ND	ND	7	19	16	3	0	2	0	0	ND	47	0.05
Sand shiner	ND	ND	ND	0	0	0	0	9	10	8	0	ND	27	0.03
Channel catfish	ND	ND	ND	0	1	0	0	8	3	4	4	ND	20	0.02
Emerald shiner	ND	ND	ND	0	0	0	0	5	10	4	0	ND	19	0.02
Rainbow trout	ND	ND	ND	2	1	11	2	0	2	0	0	ND	18	0.02
Bluegill	ND	ND	ND	0	0	1	0	0	0	9	1	ND	11	0.01
Coho salmon	ND	ND	ND	4	3	0	0	0	1	0	0	ND	8	0.01
Lake whitefish	ND	ND	ND	3	2	2	0	0	0	0	0	ND	7	0.01
Mottled sculpin	ND	ND	ND	0	0	0	2	0	3	1	1	ND	7	0.01
Burbot	ND	ND	ND	1	0	0	1	0	2	0	2	ND	6	0.01
Round whitefish	ND	ND	ND	0	0	0	0	0	0	1	2	ND	3	<0.01
Longnose dace	ND	ND	ND	1	0	0	0	0	0	2	0	ND	3	<0.01
Silver redhorse	ND	ND	ND	0	0	0	0	2	0	0	1	ND	3	<0.01
Brown trout	ND	ND	ND	0	0	1	1	0	0	0	1	ND	3	<0.01
Largemouth bass	ND	ND	ND	0	0	1	0	0	0	1	0	ND	2	<0.01
Ninespine stickleback	ND	ND	ND	1	0	0	1	0	0	0	0	ND	2	<0.01
Brook silverside	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Blacknose dace	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Shorthead redhorse	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Northern pike	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Blacknose shiner	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Smallmouth bass	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Walleye	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Black bullhead	ND	ND	ND	0	1	0	0	0	0	0	0	ND	1	<0.01
Bluntnose minnow	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Fathead minnow	ND	ND	ND	0	0	1	0	0	0	0	0	ND	1	<0.01
Rock bass	ND	ND	ND	0	0	0	0	0	0	1	0	ND	1	<0.01
Grass pickerel	ND	ND	ND	0	0	0	1	0	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	7798	14512	27245	22867	16173	3305	7081	2615	ND	101596	

Table 28. Number of fish caught by standard series trawling, gillnetting, and seining in D. C. Cook Plant study areas, southeastern Lake Michigan, 1982. ND = no data.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Percent
Yellow perch	ND	ND	ND	110	27	1102	2339	1778	5597	1053	5629	ND	17635	35.54
Spottail shiner	ND	ND	ND	552	1733	3005	1366	1009	2673	318	2189	ND	12845	25.88
Alewife	ND	ND	ND	206	1383	1159	406	2097	2688	58	240	ND	8237	16.60
Rainbow smelt	ND	ND	ND	1619	4594	490	42	646	16	235	195	ND	7837	15.79
Bloater	ND	ND	ND	0	8	1415	0	0	0	34	4	ND	1461	2.94
Gizzard shad	ND	ND	ND	0	0	0	3	37	79	26	244	ND	389	0.78
Trout-perch	ND	ND	ND	16	10	99	53	33	68	1	0	ND	280	0.56
Slimy sculpin	ND	ND	ND	184	14	1	0	0	0	0	0	ND	199	0.40
Lake trout	ND	ND	ND	5	2	0	0	0	1	38	130	ND	176	0.35
White sucker	ND	ND	ND	6	8	44	35	46	18	6	6	ND	169	0.34
Johnny darter	ND	ND	ND	4	23	24	3	4	30	3	1	ND	92	0.19
Common carp	ND	ND	ND	37	15	12	5	3	2	5	5	ND	84	0.17
Longnose sucker	ND	ND	ND	6	6	12	0	13	4	8	1	ND	50	0.10
Chinook salmon	ND	ND	ND	3	4	12	1	2	0	2	1	ND	25	0.05
Brown trout	ND	ND	ND	12	2	4	0	2	0	0	4	ND	24	0.05
Freshwater drum	ND	ND	ND	0	0	1	1	2	14	0	0	ND	18	0.04
Emerald shiner	ND	ND	ND	6	1	2	1	0	6	1	0	ND	17	0.03
Sand shiner	ND	ND	ND	5	0	1	1	1	3	1	0	ND	12	0.02
Mottled sculpin	ND	ND	ND	6	4	0	0	0	0	0	0	ND	10	0.02
Channel catfish	ND	ND	ND	0	0	2	2	0	4	0	1	ND	9	0.02
Shorthead redhorse	ND	ND	ND	0	0	3	1	0	4	0	0	ND	8	0.02
Quillback	ND	ND	ND	0	0	0	0	2	4	0	0	ND	6	0.01
Silver redhorse	ND	ND	ND	0	0	0	1	2	1	0	1	ND	5	0.01
Lake whitefish	ND	ND	ND	1	0	0	0	0	0	0	4	ND	5	0.01
Walleye	ND	ND	ND	0	0	0	0	0	0	1	3	ND	4	0.01
Rainbow trout	ND	ND	ND	3	0	0	1	0	0	0	0	ND	4	0.01
Round whitefish	ND	ND	ND	1	0	0	0	0	0	2	0	ND	3	0.01
Coho salmon	ND	ND	ND	1	2	0	0	0	0	0	0	ND	3	0.01
Burbot	ND	ND	ND	1	0	0	0	0	0	1	1	ND	3	0.01
Largemouth bass	ND	ND	ND	0	0	0	1	0	0	0	1	ND	2	<0.01
Longnose dace	ND	ND	ND	1	1	0	0	0	0	0	0	ND	2	<0.01
Ninespine stickleback	ND	ND	ND	0	2	0	0	0	0	0	0	ND	2	<0.01
Central mudminnow	ND	ND	ND	2	0	0	0	0	0	0	0	ND	2	<0.01
Banded killifish	ND	ND	ND	0	0	0	0	0	0	0	1	ND	1	<0.01
Northern pike	ND	ND	ND	0	0	0	0	0	1	0	0	ND	1	<0.01
Golden shiner	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Common shiner	ND	ND	ND	1	0	0	0	0	0	0	0	ND	1	<0.01
Bluegill	ND	ND	ND	0	0	0	1	0	0	0	0	ND	1	<0.01
Golden redhorse	ND	ND	ND	0	0	0	0	1	0	0	0	ND	1	<0.01
Totals	ND	ND	ND	2788	7839	7388	4263	5679	11213	1793	8661	ND	49624	

anomaly can be partially explained by low pumping rates during April and May 1978, which is the usual time of maximum impingement of alewife. These low pumping rates in the spring thus led to substantially reduced total impingement losses in 1978 when compared to other years of two-unit operation when spring pumping rates were "average" during this period. A second example of the difficulty in explaining changes is related to physical conditions in the lake (water temperature, storms, currents) interacting with the differing behaviors of age-groups of alewives (Appendixes 10, 12, 14, 16, 18, 20, 22, 24). The peak years of impingement, 1980-1982, occurred in spite of a general decline in populations of alewife in Lake Michigan (Jude and Tesar 1985). However, a different group of fish in a different month in each of the 3 years was responsible for a substantial proportion of total numbers and biomass of fish impinged in each of the 3 years. In 1980, large numbers of adults were impinged in April-May (Appendix 19), in 1981, yearlings impinged during May-June (Appendix 21) was the dominant group in total losses, while for 1982, yearlings and adults impinged in June (Appendix 23) comprised the highest fraction of losses.

Therefore, it appeared that physical factors which resulted in concentrating certain age-groups of alewives or making them more susceptible to impingement because of high pumping rates during these periods of susceptibility could explain much of the variability in impingement rates observed. Alewives illustrate at least two of these conditions. As nearshore water warms during spring, fish follow the warm-water mass and concentrate near shore (Wells 1968, Jude et al. 1979, Tesar and Jude 1985). If the plant operates at or near capacity and without substantial interruption during April and May, large numbers of fish of many species are impinged, but alewives

dominate the loss. This was the case in 1975 (one-unit operational) and 1980 (both units operational) (Tables 2, 12); during both years alewives accounted for over 75% of the total impingement loss (Fig. 2). Yearly pumping volumes were similar during 1978 and 1980 (2.4×10^9 vs. 2.8×10^9 m^3); however, volume pumped during April-May 1978 was low, while in 1980 it was high (Table 18). The reduced flow in spring 1978 resulted in considerably lower total alewife losses (0.2 million) compared with 1980 (1.8 million) even though pumping volumes for the year were comparable and alewife populations in Lake Michigan had declined over that period. High impingement losses in 1978 occurred among species common in nearshore water during late summer through autumn, particularly spottail shiner, rainbow smelt, and trout-perch (Fig. 3).

Despite the declining populations of alewives in Lake Michigan during the 1980s, alewives continued to be impinged in large quantities, and they even began to comprise a larger fraction of impingement losses over this period (1980-1982) compared with the earlier years, 1975-1979 (Fig. 4). Clupeids, in general, may be particularly vulnerable to impingement. At water intakes throughout Lake Michigan, alewives were the most often impinged species (Benda and Gulvas 1976, Sharma and Freeman 1977), while gizzard shad were most often impinged at plants in southern Lake Huron and Lake Erie (Benda and Houtcooper 1976, Eisele and Malaric 1977). Gizzard shad and threadfin shad were the most often impinged fish at power plants on southern reservoirs and estuaries (Freeman and Sharma 1977, Loar et al. 1977).

By 1980, both units were operating at full capacity for extended periods of time. Volume of cooling water pumped annually during 1980-1982 was notably higher than during any previous year and leveled off around 2.7×10^9 m^3/yr (Table 18). Beside the decline in alewife populations, there were a few other

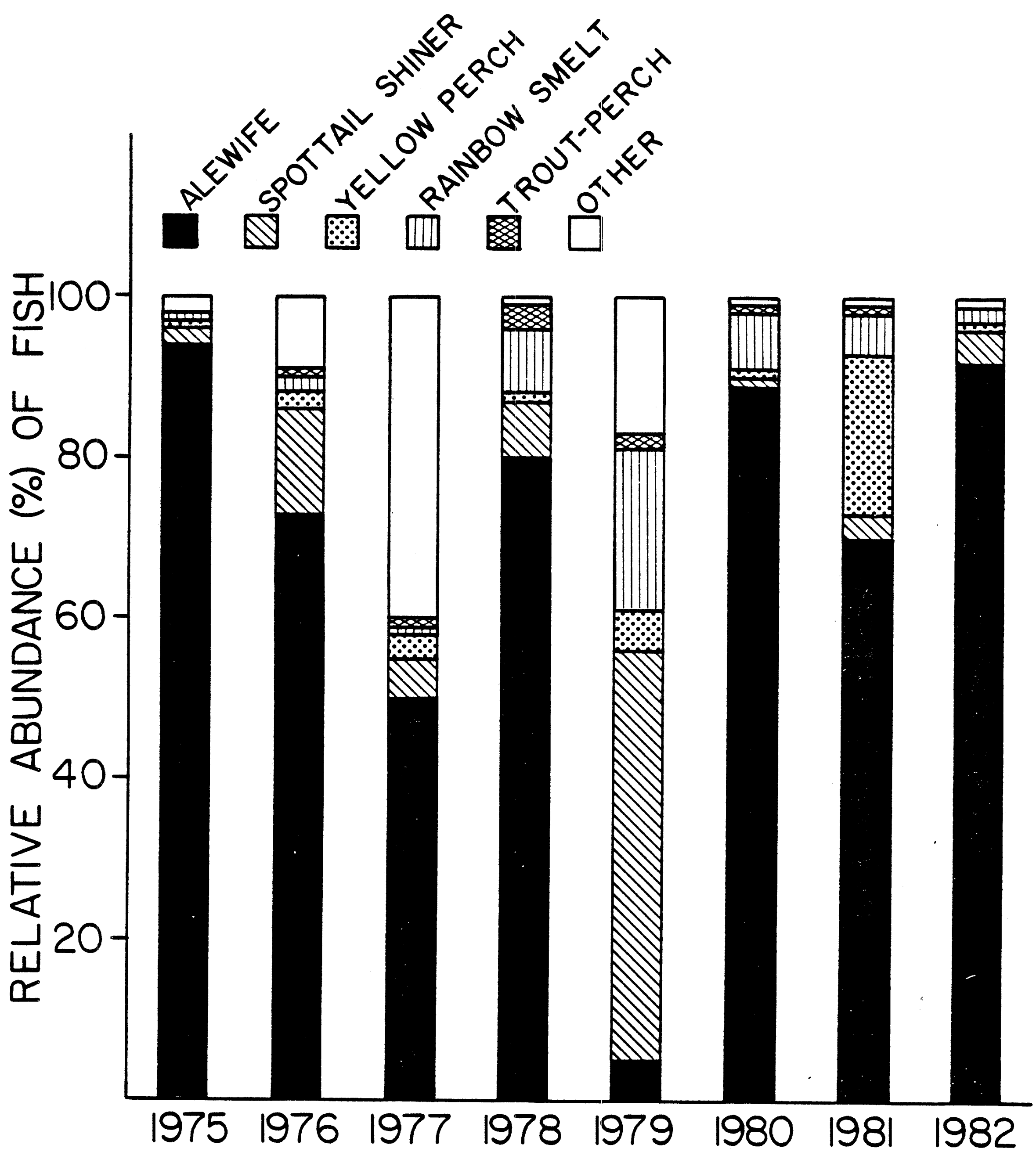

Figure 2. Species composition of the total number of fish impinged during spring (March, April, May) 1975-1982 at the D. C. Cook Plant, southeastern Lake Michigan. Spring was defined as months of steadily rising water temperature.

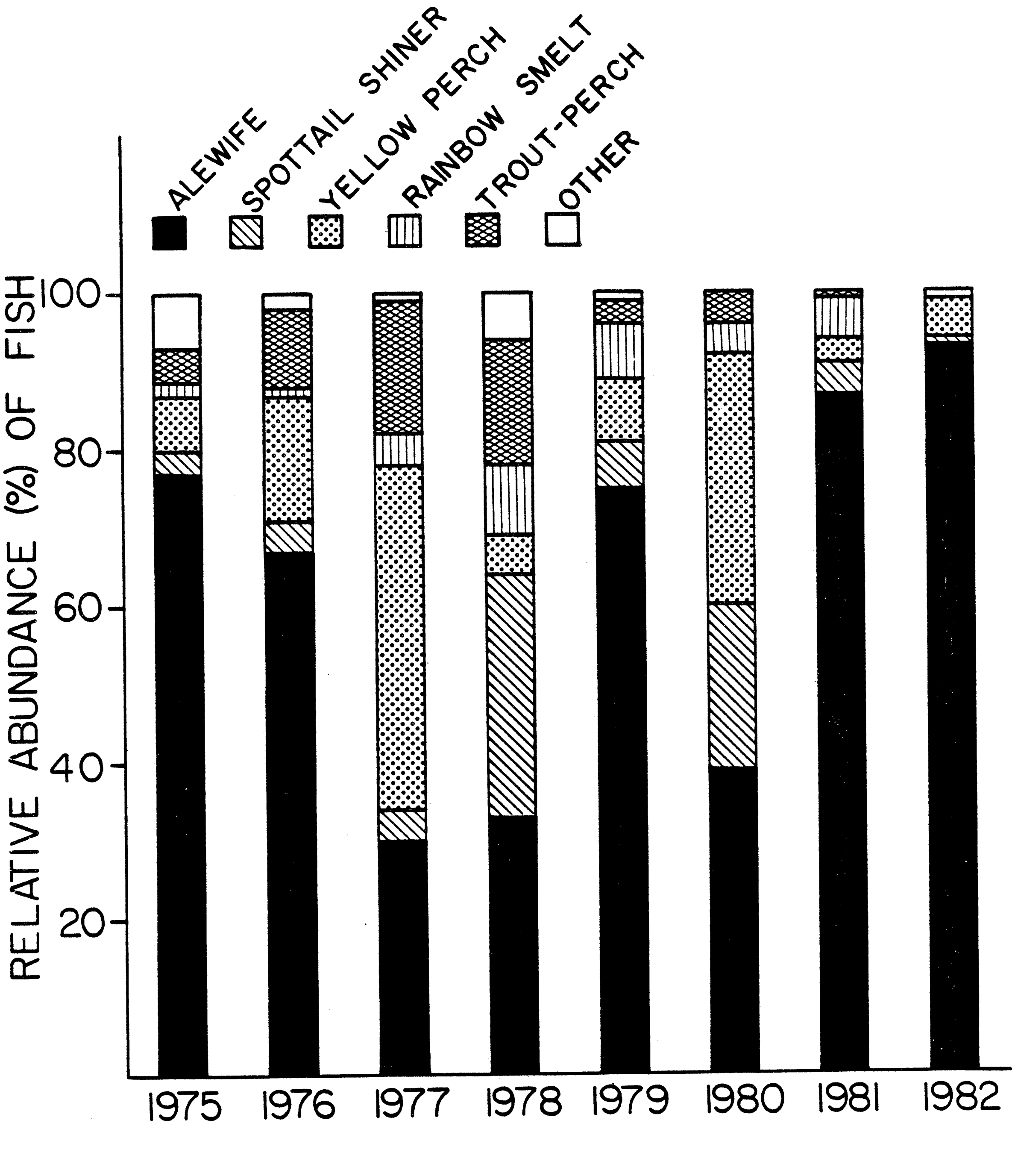

Figure 3. Species composition of the total number of fish impinged during summer (July, August, September) 1975-1982 at the D. C. Cook Plant, southeastern Lake Michigan. Summer was defined as months of maximum average temperature.

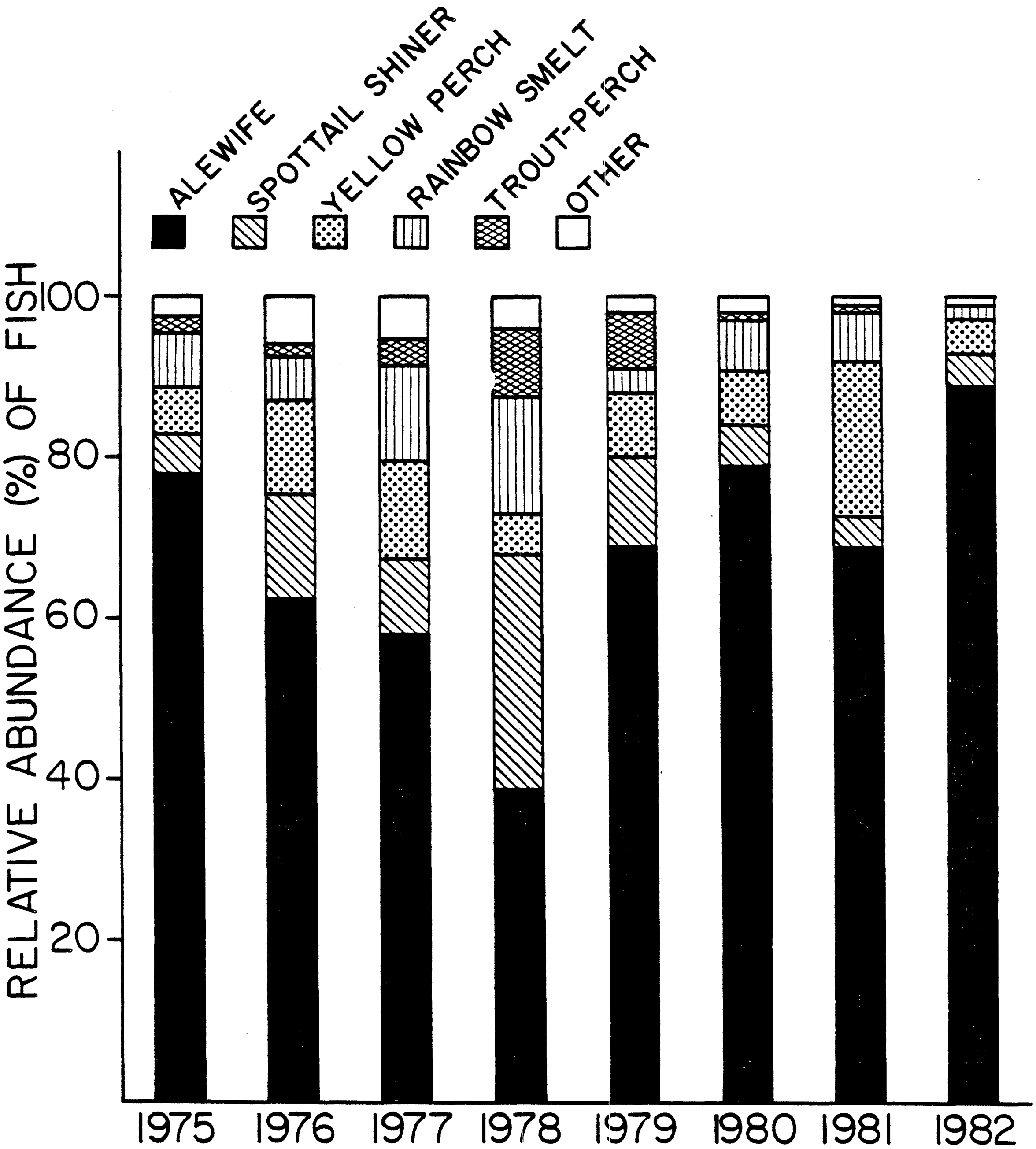

Figure 4. Species composition of the total number of fish impinged each year during 1975-1982 at the D. C. Cook Plant, southeastern Lake Michigan.

notable shifts in species composition of fish impinged during these years that were more closely related to fish population changes in the lake than to changes in cooling water flows. In 1980 and 1981, there was more than a twofold increase in number of yellow perch impinged annually (Fig. 4), probably reflecting the increasing abundance of yellow perch as alewife, a suspected predator of yellow perch larvae, declined (Fig. 5, Tables 19-28; Jude and Tesar 1985). Rainbow smelt populations also increased during the early 1980s in response to the alewife decline, and rainbow smelt were also impinged in dramatically higher numbers during 1980-1981 than during earlier years (Fig. 4, Table 1), as well as being abundant in field catches (Fig. 5, Tables 19-28).

During 1975-1979 (one unit operation), an average of 160 salmonids was impinged annually. Lake trout was the most commonly impinged salmonid during these years. An average of over 1,000 salmonids was impinged annually over 1980-1982 (Tables 12, 14, 16). Most of these fish were juvenile chinook salmon (875 - probably newly planted) in 1980, adult and juvenile lake trout (517 fish) in 1981, and adult coho salmon (530 fish) in 1982.

Impingement losses for most species declined during 1982, most notably for rainbow smelt, trout-perch, and bloaters. Lake-wide population fluctuations may have been partially responsible (Jude and Tesar 1985), but much of the decline in number of fish impinged can probably be attributed to local water temperatures, which were unusually warm during July-September 1982 (Table 29). Because there was only one notable upwelling during this time (Appendixes 1-8), the thermocline was relatively stable and intersected the bottom far offshore. Many species concentrate at or near the thermocline

Table 29. Lake Michigan water temperatures (C) measured at the St. Joseph Municipal Water Plant; intake depth - 5.8 m. Data are monthly means of the daily average of maximum and minimum temperatures.

	Month											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1973	0.5	0.6	4.2	7.1	10.6	17.9	18.8	19.7	16.4	15.7	9.7	4.1
1974	1.2	1.1	3.7	7.5	11.3	14.9	17.2	16.5	16.2	13.3	9.2	3.0
1975	1.3	1.1	2.1	5.4	10.9	16.2	19.5	15.5	17.3	14.5	10.9	4.1
1976	1.1	2.1	5.4	9.6	11.0	16.7	19.2	20.5	18.0	14.6	8.3	2.0
1977	1.1	1.1	3.5	8.7	12.4	14.7	18.6	18.5	15.9	12.1	8.5	2.5
1978	1.7	1.4	1.5	5.6	10.2	13.7	14.1	17.9	18.4	14.0	10.1	3.1
1979	1.3	1.8	2.6	6.6	10.6	14.1	18.0	19.5	17.3	14.5	10.3	5.4
1980	3.0	2.4	2.4	5.9	9.8	14.3	16.7	16.4	15.2	12.4	7.2	2.6
1981	0.9	1.2	3.2	8.2	9.8	15.4	14.8	19.2	18.2	12.0	8.5	3.6
1982	1.2	0.7	1.8	6.3	10.7	13.7	18.5	20.1	18.5	14.4	8.9	5.8
1973-1982	1.3	1.4	3.0	7.1	10.7	15.1	17.6	18.4	17.2	13.8	9.2	3.6

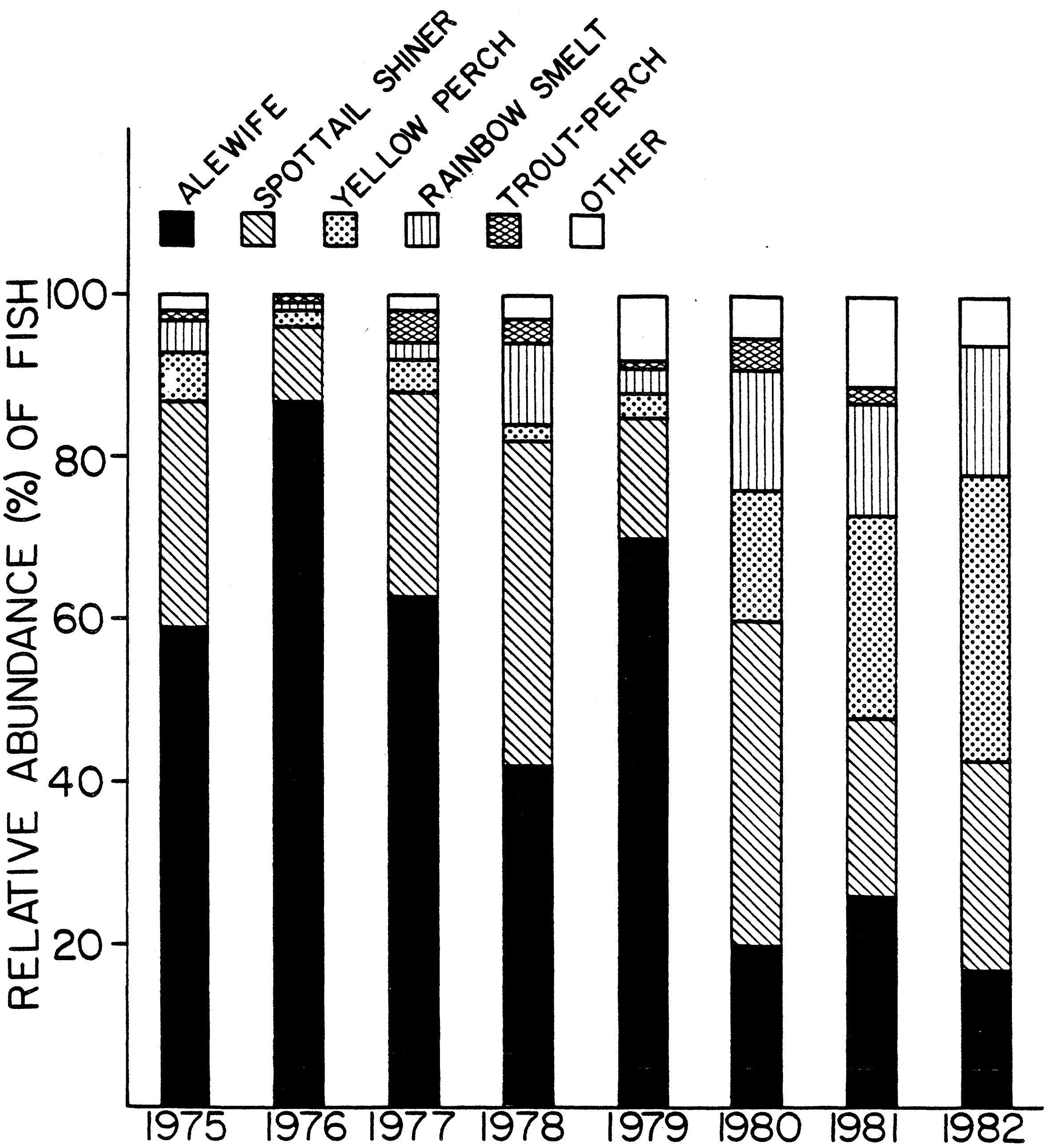

Figure 5. Species composition of the total number of fish collected in standard-series fishing each year during 1975-1982 at the D. C. Cook Plant, southeastern Lake Michigan.

(Brandt 1980, Brandt et al. 1980), and thus were probably concentrated at depths greater than the intake depth during the late summer months of 1982.

Over a period of several days in May 1980, more than half of the alewives appeared to have been dead before they were impinged. These fish are easily distinguished from fish that were alive when impinged for three reasons. They are emaciated, the scales and skin grayish and dull, and many are limp and compressed. In contrast, newly impinged fish are often alive when they enter the trash baskets, and most samples are placed in freezers within 5-6 hr of being impinged, thus preserving their color and form. Alewives which were already dead appeared in impingement samples immediately following unusually high impingement rates in April and May 1980. Because there was no corresponding increase in the number of dead alewives washed up on the beach or collected in our May field samples, the impinged alewives probably died in the forebay from starvation and stress caused by overcrowding.

During 1981 and 1982, both dead fish and debris from all impingement samples processed in the lab were weighed and recorded. There was no recurrence of the high proportion of dead fish that appeared in 1980. Of the total weight of impinged fish samples in both 1981 and 1982, weight of dead fish was about 1%. Trash weight equaled 3% of the weight of impinged fish samples in 1981 and 2% in 1982.

SEASONAL ABUNDANCE

Number of fish impinged per month at the Cook Plant varied seasonally (Tables 2-17). Most fish were impinged during April through October; few were impinged during winter. Each year was characterized by a month of peak

impingement during June or July, and often another (usually secondary) peak in spring (April, May) or fall (September-November).

Though factors influencing impingement overlapped over seasons and years, the dynamics contributing to heavy impingement losses differed from season to season. During spring, many fish are impinged as they move shoreward seeking warm water. Warming of Lake Michigan water during April is characterized by a narrow band of warmer, inshore water, separate and distinct from colder, offshore water. Formation of a pronounced and persistent thermal bar separating inshore and offshore water masses (Huang 1969, Mortimer 1973), may act as a barrier, concentrating fish in a narrow band of warm, nutrient-rich water close to shore. A thermal bar was present within 2 or 3 km of shore during periods of high impingement losses in April 1975 and 1980. High fish impingement rates during this time may have resulted from increased activity and movement of fish and higher densities of fish inshore.

In June and July, impingement losses may be quite high as fish move shoreward to spawn. Among the more abundant species, alewife, spottail shiner, yellow perch, and trout-perch spawn during these months. Numbers of fish impinged during these months may also be strongly influenced by upwelling, which increases fish activity and causes many fish to move shoreward seeking preferred warmer temperature (Wells 1968, Emery 1970, Jude et al. 1979). Rainbow smelt and bloater, which prefer cold water (Wells 1968, Jude et al. 1979), may accompany cold, upwelled water inshore. Exceptionally high impingement losses during July 1978 coincided with three periods of strong upwelling (Appendix 4), while in contrast during summer 1982 a low frequency of upwelling resulted in low impingement losses. Autumn impingement losses may be attributable to increased movement of fish as water temperatures

become isothermal and fish move offshore toward deeper water. In addition, impingement of large numbers of young-of-the-year (YOY) fish occurs as they attain a size which can be retained by traveling screens.

Species composition of impingement losses also changed seasonally (Figs. 2, 3, 6, 7). This was particularly notable for alewives, which comprised over 80% of spring losses, nearly 60% of summer losses, about 25% of fall losses, and about 8% of winter losses. The largest component of autumn impingement losses was YOY and yearling yellow perch; trout-perch were also common in collections. Though winter impingement losses were low, spottail shiner, yellow perch, and rainbow smelt were all impinged frequently; evidently these species remain nearshore or forage frequently nearshore during winter.

The biology of individual species is an important factor determining seasonal patterns in impingement rates. The preference of alewives for warm water accounts for their high density inshore. Peak impingement of alewives usually occurred during June or July, when alewives moved inshore to spawn. In late summer or autumn there was an increase in impingement of YOY alewives, which by this time were large enough (≥50 mm) to be retained by traveling screens (Appendices 9, 11, 13, 15, 17, 19, 21).

Spottail shiner preference for shallow depths and warm water (Wells 1968, Jude et al. 1979) affected spottail shiner impingement rates. Impingement of spottail shiners increased in March and April as spottail shiners moved shoreward seeking warmer, inshore water. Except for 1980 and 1981, impingement of spottail shiners during May and June was low (Tables 2-17); field data indicated spottail shiners were mostly inshore of the intake depth (9 m) (Tesar et al. 1985, Tesar and Jude 1985). Impinged spottail shiners

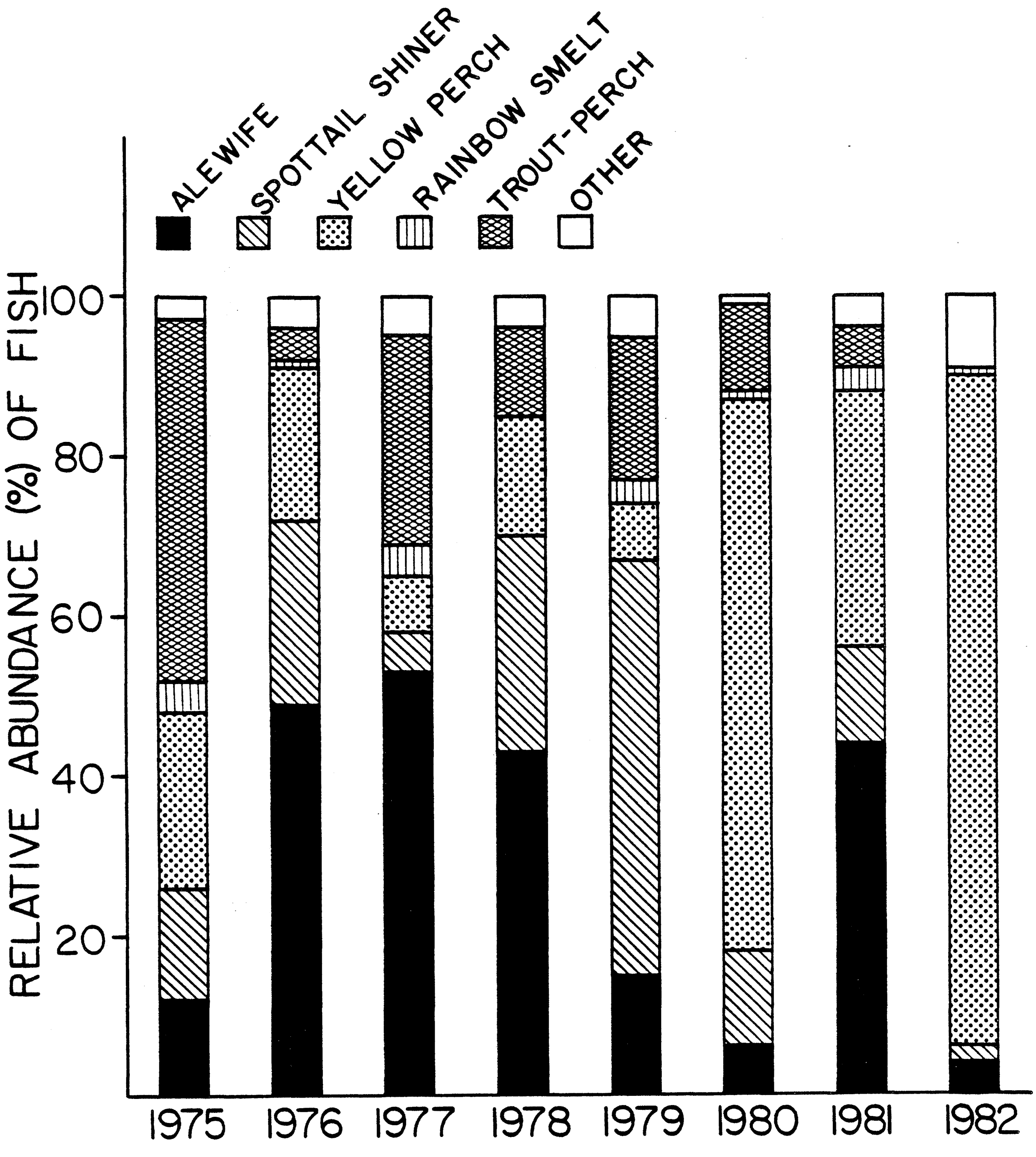

Figure 6. Species composition of the total number of fish impinged during fall (October, November) 1975-1982 at the D. C. Cook Plant, southeastern Lake Michigan. Fall was defined as months of steadily falling water temperature.

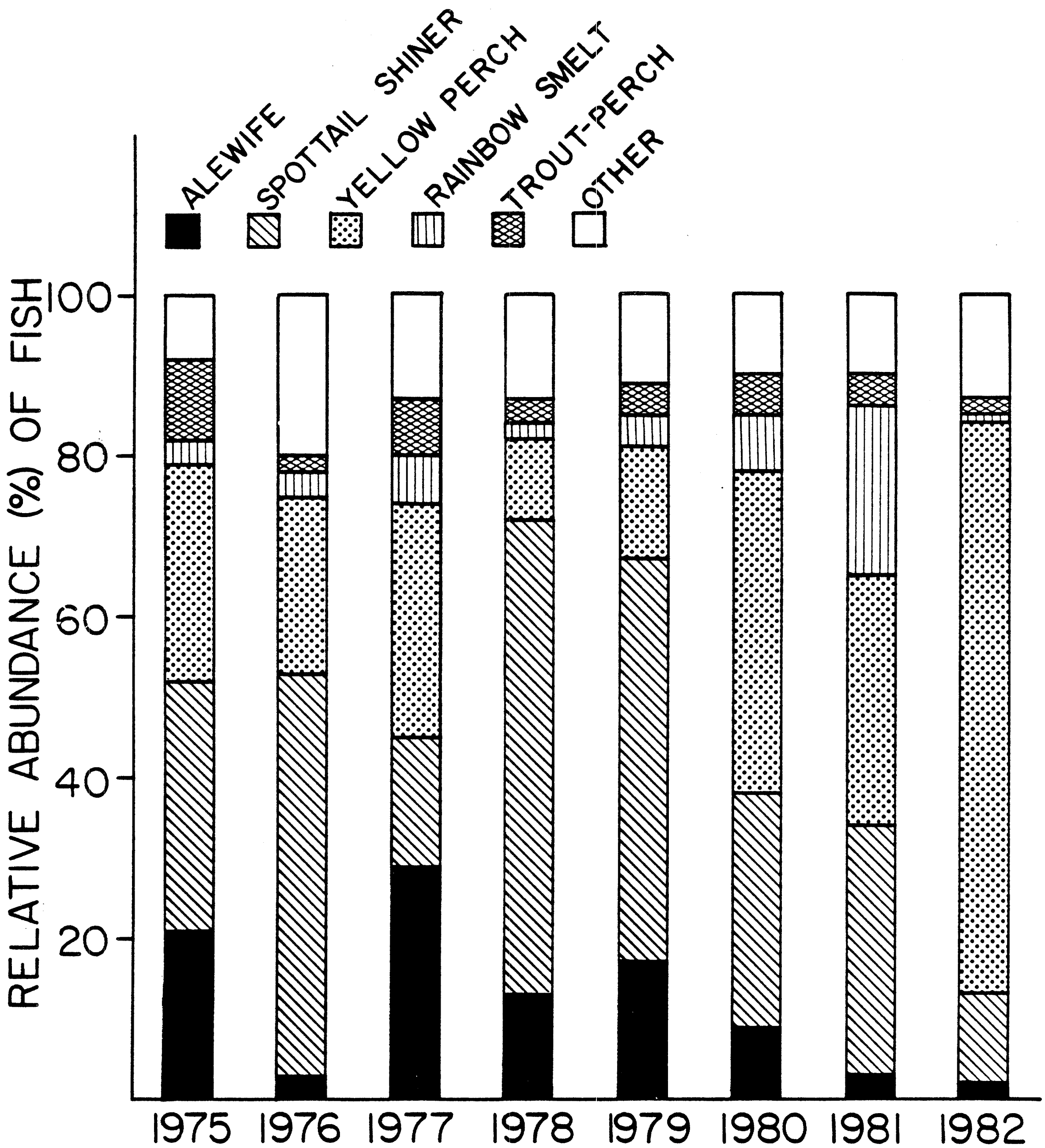

Figure 7. Species composition of the total number of fish impinged during winter (December, January, February) 1975-1982 at the D. C. Cook Plant, southeastern Lake Michigan. Winter was defined as months of minimum average water temperature.

were generally >50 mm (Appendices 25, 27, 29, 31, 33, 35, 37, 39). The minimum size retained by the traveling screens was generally 50 mm. In contrast, field-caught spottail shiners included a large component of YOY fish which were recruited to our seining gear (Appendices 26, 28, 30, 32, 34, 36, 38, 40). Peak spawning for spottail shiners occurs in July (Jude et al. 1979), when they also begin their post-spawning migration offshore. Large late summer impingement losses of spottail shiners during 1978-1980 were probably due to increased activity and offshore movement during these months. Impingement of adult spottail shiners during October was presumed to be related to their offshore migration which takes them past the influence of the intakes. A similar event occurred in 1975-1977 for YOY spottail shiners which by this time were large enough to be retained on the traveling screens (Appendices 25, 27, 29). A few spottails remained inshore all winter. Winter impingement rates seemed to be directly related to water temperature, since rates increased when water temperature in the area rose to 3°C or above, but there were exceptions. Beside water temperature, winter impingement of spottail shiners was probably affected by attraction to the warm-water plume, winter storms, and ice cover.

Impingement of trout-perch began to increase in April, becoming high in June and July. In June, trout-perch move inshore for spawning, which continues throughout summer. Impingement of trout-perch during summer was highly variable, but it appeared to coincide with upwelling or storms. Impinged fish were generally 80-150 mm in length. Over 50,000 trout-perch were impinged during July 1978, which was the highest impingement loss of trout-perch for a month in summer (Appendices 41-56). During most years, impingement losses tapered off during late summer and rose again in September

or October as offshore trout-perch migrations placed fish in the influence of the intakes. A few trout-perch were impinged during winter.

Impingement of yellow perch increased slightly in March and April, as inshore water temperatures warmed in spring. Peak impingement of yellow perch occurred during June through September, except for 1975. Because this was after the spawning season (late May-early June) for yellow perch, their mid-to-late summer abundance evidently reflected post-spawning migrations into the vicinity of the intake area after spawning in other areas of the lake (Jude et al. 1979, Dorr 1982). There is some evidence that impingement of yellow perch during summer increased sharply after storms (Lifton and Storr 1977; personal observations). Young-of-the-year yellow perch were first impinged in September and continued to be impinged during fall and winter, showing that at least some fish remained inshore through most of the winter (Appendices 57-72).

Impingement of rainbow smelt usually peaked during spring, most often during April and May. During these months, rainbow smelt move past the intake area as they migrate inshore to spawn (Jude et al. 1979). Because adult rainbow smelt prefer cold water (Wells 1968, Jude et al. 1979), they move offshore during months of warm-water temperatures. Impingement of rainbow smelt during the summer usually occurred when cold, upwelled water allowed rainbow smelt to move shoreward. During 1978 through 1981 large numbers of rainbow smelt were impinged during summer. Young-of-the-year rainbow smelt were impinged in September and October (Appendices 73-88).

Fish impingement during 1980 through 1982 was distinguished by extremely large numbers of fish impinged during April-June, beginning with the exceptionally high losses which occurred during April 1980. Losses were high

for most species during these months, particularly for alewives. Many yellow perch were impinged during June of these years, although not in previous years.

Winter impingement losses were exceptionally high during January and December 1981. The species impinged at this time were species most likely to be found inshore during winter; e.g., spottail shiner, yellow perch, trout-perch (December only), and rainbow smelt.

IMPINGED FISH COMPARED WITH FIELD-CAUGHT FISH

In general, species that were most abundant in imp.ngement collections (Tables 2-17) were also most abundant in field catches (Tables 19-28). Spottail shiners comprised a higher percentage of field catches (23% of all fish caught in standard series fishing 1975-1982, Tesar and Jude 1985) than of impingement losses (10% of total). Though spottail shiners were locally abundant, they apparently were not attracted to the intake structure and may even have avoided the area; they were most abundant inshore of the intakes (Tesar and Jude 1985). Sculpins were impinged in much higher numbers than would be predicted from field catches. Benda and Gulvas (1976) and our divers (Dorr and Miller 1974, Dorr and Jude 1980) observed that sculpins were found in much higher densities in the riprap around intake structures than on adjacent sand; their propensity for hiding in dark places and their nocturnal activity patterns probably increased their susceptibility to entrapment.

The relationship among fish impingement losses, field abundance, and volume of water circulated through the plant varied with species. An analysis was conducted using multiple correlation to determine if significant relationships existed among these three variables: fish impingement losses,

field abundance of fish, and volume of water circulated through the plant. The total weight of alewives impinged over 5-day periods, corresponding with the same 5-day periods in which our eight field sampling trips per year were performed during 1975-1982, was used for the first variable. The number of alewives gillnetted at stations in the vicinity of the intakes was the second variable, and volume of cooling water circulated during those periods was used as the third variable. There was a strong positive correlation among these three variables for alewives. The relationship between yellow perch impingement rates and the latter two variables was also positive, but less strongly so, possibly because yellow perch may be less randomly distributed throughout the area (G. Godun, unpublished manuscript, Great Lakes Research Division, University of Michigan, Ann Arbor, Mich.). For both species, field abundance was a better predictor of impingement loss than volume of cooling water pumped.

A second analysis was done by pooling data within a year, providing eight data points. In this case, volume of cooling water pumped more precisely predicted impingement (C. Madenjian, unpublished manuscript, Great Lakes Research Division, University of Michigan, Ann Arbor, Mich.). Annual field abundance of alewives was negatively correlated with annual impingement loss. Part of the reason for this finding has already been discussed, and involves the high impingement rates during 1980-1982 during the time when alewife populations lakewide were declining dramatically. These two methods (pooling and not pooling data) of comparing impingement loss with field abundance indicate that fish impingement at any given time is probably related to the momentary abundance of fish in the vicinity of the intake but may not necessarily reflect seasonal or yearly changes in the inshore abundance of

certain species. This was particularly true of alewives when yearly impingement losses (Tables 2-17) were compared with field catches (Tables 19-28). Annual impingement losses among other abundant species more closely followed field abundance but often showed 1 or 2 years when the two variables were not correlated. Annual impingement losses of trout-perch during one-unit operation (1975-1977) (Tables 2-7) and rainbow smelt during two-unit operation (1978-1982) (Tables 8-17) were negatively correlated with annual field abundance of these two species (Tables 21-28). The differences may be partially explained by limitations of field sampling, because each gear type only samples during one 24-h period each month, but this explanation alone is inadequate. Young-of-the-year fish were often more abundant in field catches than they were in impingement samples, because they were most likely to be inshore of the intakes and because they were too small to be impinged.

The years 1980 through 1982 held some especially sharp contrasts, particularly for alewives, which declined precipitously in field abundance during this time (Tables 19-28, Fig. 1; Jude and Tesar 1985) but which continued to be impinged in extremely large numbers (Tables 12-17). Several other species, particularly yellow perch, which responded positively to the alewife decline, and to a lesser extent, slimy sculpin and rainbow smelt, were more abundant during these years than previously in both field and impingement samples. Bloaters were relatively abundant in field catches during 1980-1982, particularly 1981, perhaps resulting from several intense upwellings during June and July, 1981 (Appendix 7). Impingement of bloaters was exceptionally high during this time, as it was in 1978-1979, but both impingement losses (Table 16) and field abundance (Table 28) declined in 1982. Field abundance

and population changes among all species is discussed in detail in Tesar et al. (1985), Tesar and Jude (1985), and Jude and Tesar (1985).

Disproportionately high entrapment rates may occur when fish are attracted to the riprap or the intake structures. Weather or water temperature changes also increase horizontal or vertical movements of fish, which can lead to decreased fish avoidance of the intake structure and increased impingement losses. Sculpins and yellow perch are examples of fish which are attracted to the riprap and apparently prefer that substrate over the flat, featureless sand bottom which characterizes field sampling stations. Sculpins, in particular, as confirmed by project divers (Dorr and Jude 1980), reside on the riprap almost exclusively. Divers also observed aggregations of yellow perch around the intakes (Dorr and Jude 1980), and yellow perch, sculpins, johnny darter, spottail shiner, and ninespine stickleback may use the riprap as spawning substrate (Dorr 1982).

Trout-perch and rainbow smelt, however, are examples of fish which are not normally attracted to the intakes or riprap. Even when present inshore, they may not be impinged in large numbers unless weather or water temperature changes occur. Entrapment of all fish, even those which normally are attracted to the intakes, increases when fish activity increases. Spawning, spring warming of inshore water, fall overturn, upwelling, and storms are all conditions which increase fish movement through the area of the intakes. Upwelling can force fish to move upward in the water column (Emery 1970), which increases their chances of entrapment. Fish not only are more active during storms, but may seek shelter in the lee of an intake structure (Lifton and Storr 1977). Turbidity and turbulence associated with storms may also reduce fish awareness and avoidance of the intake structure and current.

PLANT EFFECTS

Two-unit operation increased cooling water flow rate from 2.7×10^6 liters/min to 6.1×10^6 liters/min (USAEC 1977) and, during certain times of the year, increased fish impingement substantially over impingement during one-unit operation. In making comparisons of impingement rates, 1977 was not considered because so few fish were impinged compared with the preceding 2 years. Because 1977 was a year of one-unit operation, its exclusion should contribute to a more conservative estimate of the differences between one-unit and two-unit operation. Initial years of two-unit operation, 1978 and 1979, are compared separately from 1980-1982 because Unit 2 pumping during 1978-1979 was erratic, especially during the spring, a key high period of impingement loss. The full effect of sustained two-unit pumping was not observed until 1980.

The largest percent increase in impingement losses for spottail shiner, trout-perch, and rainbow smelt occurred in 1978-1979 (Table 30). This increase was probably a direct result of the plant pumping schedule which increased pumping rates dramatically when Unit 2 came on line in 1978. However, monthly pumping volumes were erratic and seldom involved more than three pumps for any extended period of time during spring and early summer of these 2 years, which resulted in lower impingement rates for fish usually abundant during these months. In contrast, volume of water pumped during July-December, 1978-1979 was high (Table 18) and impingement losses among species which were abundant during these months were substantial (Tables 8-11). Both units were operating at nearly full capacity during most of the spring and early summer months of 1980 through 1982 (Table 18), with

Table 30. A comparison between two periods of the percent change in volume of water pumped and number of fish impinged annually at the D. C. Cook Plant. Comparisons are among years of one unit operation (1975-1976), years when two units operated sporadically (1978-1979), and years of full two unit operation (1980-1982). The year 1977 was not included because volume pumped was exceptionally low and not considered characteristic of full one unit operation. See text for full explanation.

	Comparison		
	1975-1976 to 1978-1979	1978-1979 to 1980-1982	1975-1976 to 1980-1982
Volume of water pumped	87	15	114
<u>Major fish species</u>			
Alewife	97	374	832
Spottail shiner	577	-35	342
Yellow perch	114	463	1,103
Trout-perch	303	-64	12
Rainbow smelt	1,226	112	2,721

concomitant high impingement losses (Tables 12-17) among species (especially alewife and yellow perch) which are normally abundant during these months. When the period 1975-1976 (consistent one-unit operation) was compared with the period of consistent two-unit operation (1980-1982), a 114% increase in volume of water pumped was accompanied by increased impingement losses among major species ranging from 342% to 2,721% (Table 30). Trout-perch were an exception; losses declined during 1980-1982. Field abundance data (Jude and Tesar 1985, Tesar and Jude 1985) showed trout-perch declined substantially in 1982 compared to earlier years, possibly due to increased predation by the burgeoning yellow perch population.

Data from 1980 to 1982 indicate that full two-unit operation can result in extremely large numbers of fish impinged in a short period of time. In 1980, over 1 million fish were impinged during a 3-wk period in April and May. Zion Station, a nuclear power plant in Illinois (Lake Michigan) experienced a similar influx of alewives during May 1975 (Kitchel 1975). Heavy impingement losses may possibly affect local abundance of impacted species, especially in combination with total impingement losses within the southern basin of Lake Michigan. Jensen et al. (1982) estimated that water withdrawal through all intakes on Lake Michigan reduced alewife biomass by nearly 3%, based on 1975 data. Many fish impinged at the Cook Plant during peak periods in 1978 through 1982 were YOY or yearlings which had not spawned (Appendices 15-23). Losses among this age-group might be particularly detrimental because of their high production potential (Rago 1979).

Rago (1979), in calculating production forgone due to entrainment and impingement of larval and adult fish, indicates that most production forgone results from losses among post-larvae through yearlings. Through 1981, over

80% of alewife production forgone was attributable to entrainment (P.J. Rago, unpublished ms); however, impingement of YOY and yearlings contributed significantly to rainbow smelt losses and dominated yellow perch production forgone (Rago 1979). If alewives continue to decline in abundance and are replaced inshore by other species, impingement losses may become increasingly important to total production forgone. Jensen et al. (1982) felt that the biomass of fish impinged on Lake Michigan had more impact on stocks of abundant species than did entrainment of larvae. His prediction is confounded by the high predation pressure on alewife by salmonids (Stewart et al. 1981; unpublished data, Great Lakes Research Division). Few alewives, but many rainbow smelt, were impinged during 1983 and 1984, and yellow perch were very abundant in gill nets set at Cook Plant stations for radiological monitoring (E. Mallon, personal communication, D. C. Cook Plant, Bridgman, Mich.).

MITIGATIVE MEASURES FOR IMPINGEMENT

There are several structural or functional modifications of the intake system which might reduce or eliminate impingement and even entrainment of fish. Engineering and economic constraints of most of these alternatives are discussed at length by IMPC (1979). Bimber et al. (1984) discuss the effectiveness of several alternatives in reducing entrainment.

Perhaps the most favored system is fine-mesh, wedge-wire screens. Intakes of this type currently installed at the J. H. Campbell Plant eliminated impingement and reduced entrainment for some species (Jude et al. 1982, Zeitoun et al. 1981). Smaller mesh sizes (mesh size of Campbell screens is 9.5 mm) might reduce entrainment further, but not substantially (Schneeberger and Jude 1981). Smaller mesh size, however, requires more

frequent cleaning and reduces flow (IMPC 1977). The suitability of this technology for a plant with cooling water requirements as large as Cook's is still unproven. Because of the low flow velocities characteristic of this system, construction would require an intake field substantially larger than currently exists at the Cook Plant, resulting in a significantly larger riprap area which would provide substantial spawning habitat. This could result in an actual increase in entrainment of larvae of certain species, such as yellow perch (Jude et al. 1982) and possibly lake trout, which would be attracted to the area.

A barrier net which surrounds the intake structure and prevents fish entrapment was used with apparent success at Zion Station, Lake Michigan (Kitchel 1975) and in Lake Erie (J. Gulvas, personal communication, Consumers Power Company, Jackson, MI). The 5-cm stretch-mesh net was installed during April-November and appeared to be effective in reducing impingement of adult alewives. A fine-mesh benthic net placed around the intake at Ontario Hydro's Nanticoke Plant in Lake Ontario helped reduce impingement losses by 64-84% (Foster 1981). The net was not size-selective but was species-selective, deterring emerald shiner, rock bass, spottail shiner, trout-perch, white bass, and yellow perch more effectively than alewife and some other species. The barrier net was not recommended, however, because it was vulnerable to wave action and ice scour, a drawback which should not be a problem if the nets were removed seasonally. A barrier net is a possibility for the Cook Plant, but a more careful study should be made of the effectiveness and maintenance requirements of the nets which have been tried in the Great Lakes.

Other possibilities for alleviating impingement losses include operational strategies which would require no structural changes in the

intake. The most effective approach would be to curtail volume of water pumped through the plant during months of maximum impingement. Over 80% of all fish were impinged from April through July, though most YOY were impinged from August through October. During two-unit operation, an average 54% of annual impingement losses have occurred in 1 month, June, while the second-largest losses usually occurred in May. Curtailment of volume of water pumped through the plant during May-July should result in impingement of less biomass, while curtailment during September and October should result in fewer YOY impinged. A lower volume of water pumped could be achieved by scheduling refueling and maintenance during these months. Reducing volume pumped without reducing power output by the plant would result in a ΔT exceeding the maximum ΔT of 22 °F + 1 °F for Unit 1 or 17 °F + 1 °F for Unit 2 specified by Nuclear Regulatory Commission environmental technical specifications. Our analyses of plume effects (IMPC 1977), as well as those of others (Kelso and Minns 1975), indicate no biological reason why a compromise could not be reached to reduce fish impingement losses at the plant. Impact on other biota (phytoplankton, zooplankton, benthos) would also have to be taken into consideration.

Reducing flow at night might also reduce impingement. Though we made no diel studies, there is some evidence from other plants that more fish are impinged at night (Benda and Houtcooper 1976), and more fish larvae are entrained at night at the Cook Plant (Bimber et al. 1984).

SUMMARY

The D. C. Cook Nuclear Power Plant is a two-unit, 2,200 mW utility located on the shores of southeastern Lake Michigan. The plant began Unit 1

operation in 1975, and Unit 2 came on line in 1978. Both units together require 6.3×10^6 liters/min for cooling water which is drawn from three intakes located in about 7 m of water. Water entering the plant is screened first with 6.6-cm trash bars, then with 9.5-mm bar mesh traveling screens. Juvenile and adult fish too large to pass through the screens are retained, removed with a jet spray, and sluiced into larger baskets. Plant personnel bagged and froze all fish, and University of Michigan personnel processed samples of all fish in 1975 and samples from every fourth day in 1976-1982. These data were used to generate impingement losses for all species on a monthly and annual basis. In addition, we compared trends in impingement losses with our concurrently collected field samples and with the total volume of water pumped through the plant.

Annual impingement losses at the D. C. Cook Plant over 1975-1982 ranged from 53,190 (1,833.34 kg) fish in 1977 to 2,307,654 (71,208.81 kg) in 1980. Each year was characterized by a month of peak impingement during June or July and often a secondary peak in spring (April-May). Pooled over years, alewife comprised over 68% of the total loss, spottail shiner 10%, yellow perch 9%, trout-perch 5%, rainbow smelt 4%, slimy sculpin 2%, while 55 less common species made up the remaining loss (<2%).

During consistent two-unit operation in 1980-1982, an average of over 1,000 salmonids was impinged per year. The fish comprising the highest percentage of losses varied each year from juvenile chinook salmon in 1980 to lake trout in 1981, and adult coho salmon in 1982.

During May 1980, we recorded a large number of previously dead alewives in impingement collections. We felt these fish entered the forebay during the

high impingement events in late April and May and died in the forebay from stress and overcrowding.

The variability among years in impingement losses was a function of abundance of various age-groups of fish in the lake and their behavior during major physical events (thermal bar, storms, strong current). A second important factor was pumping rate, and whether maximum pumping rates occurred during certain key months when fish were particularly susceptible to impingement. In addition, during the early 1980s, alewives suffered a dramatic decline in Lake Michigan, with several species (yellow perch, rainbow smelt, bloater) increasing in response to the decline. However, alewives still comprised a high percentage of the losses in 1980-1982, which is partially related to high pumping rates in the spring and persistence of the thermal bar. More recent data collected by power plant personnel suggest that alewives now comprise a substantially lower percentage of the catch. As yellow perch, rainbow smelt, and bloaters increased in abundance in Lake Michigan, they also were impinged in higher numbers.

Biology and behavior were important determinants of the susceptibility of individual species to impingement. Seasonal and diel movements because of spawning and feeding, and in response to temperature, brought different species at different times into the influence of the intakes. Any factors which decreased the avoidance capabilities of fish, such as darkness, storms, or high currents, caused increased impingement of species in the vicinity of the intakes. Alewives were particularly susceptible as they moved shoreward in spring and concentrated within the thermal bar seeking warm water. Persistence of the bar led to impingement of large numbers of alewives and other species each spring. The preference of spottail shiners for nearshore

areas reduced their impingement susceptibility, while other species, such as sculpins and johnny darters, preferred the riprap around the intakes and were impinged in large numbers as a consequence. Upwellings resulted in the movement nearshore of cold water species, such as lake trout, bloaters, and rainbow smelt. Their impingement losses during summer appeared to be directly related to upwelling frequency.

Unit 2 became fully operational in 1978, but consistent pumping rates were not maintained until 1980. When the period 1975-1976 (consistent one-unit operation) was compared with 1980-1982 (consistent two-unit operation), a 114% increase in volume of water pumped was accompanied by increased impingement losses among major species ranging from 342% to 2,721%. Full two-unit operation resulted in the impingement of over 1 million fish during a 3-wk period in April-May, 1980.

In general, species that were most abundant in field catches were also most abundant in impingement collections, with alewife dominant in both. Spottail shiners comprised a higher proportion of field collections than impingement losses because they were concentrated inshore of the intakes and may have even avoided them. Other species, such as sculpins, comprised a low percentage of field catches, but were attracted to the riprap and impinged in high numbers.

Production forgone estimates (Rago 1979) showed that over 80% of the production loss for alewife was attributable to entrainment. Impingement of YOY and yearlings contributed significantly to rainbow smelt losses and dominated yellow perch production forgone losses.

Reduction in impingement losses could be obtained by installation of wedge-wire screens, but cost constraints, biofouling, and operational

feasibility in shallow water may preclude their use. Barrier nets, although troublesome, may be another mitigative device useful in curtailing impingement losses, particularly if barrier net use targeted known periods of high impingement losses (e.g., 80% by number of all fish was usually impinged in April-July). Another avenue of approach involves changes in plant operation, most of which would require Nuclear Regulatory Commission approval. This would include curtailment of volume of water pumped through the plant during high impingement periods. Scheduling maintenance and refueling during these months would accomplish that. Decreased volume could also be attained by increasing the ΔT of the cooling water. Reduced flow at night, a period of documented higher impingement rates, would also result in lowered impingement losses.

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LITERATURE CITED

Benda, R. S., and J. A. Gulvas. 1976. Post-operational effects of the Palisades nuclear power plant. Pages 243-250 in G. W. Esch and R. W. Mc Farlane, eds. Thermal Ecology Symposium, Institute of Ecology, Univ. Georgia, Augusta, Ga.

Benda, R. S., and W. C. Houtcooper. 1976. Impingement studies at 16 electro-generating plants in Michigan. Pages 291-315 in L. D. Jensen, ed. Third National Workshop on Entrainment and Impingement. Ecological Analysts, Inc., Melville, N.Y.

Bimber, D. L., M. Perrone, Jr., L. S. Noguchi, and D. J. Jude. 1984. Field distribution and entrainment of fish larvae and eggs at the Donald C. Cook Nuclear Power Plant, southeastern Lake Michigan. Spec. Rep. No. 105. Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 320 pp.

Brandt, S. B. 1980. Spatial segregation of adult and young-of-the-year alewives across a thermocline in Lake Michigan. Trans. Amer. Fish. Soc. 109:469-478.

Brandt, S. B., J. J. Magnuson, and L. B. Crowder. 1980. Thermal habitat partitioning by fishes in Lake Michigan. Can. J. Fish. Aquat. Sci. 37:1557-1564.

Dorr III, J. A. 1982. Substrate and other environmental factors in reproduction of the yellow perch (*Perca flavescens*). Ph.D. thesis, Univ. Mich., Ann Arbor, Mich. 276 pp.

Dorr III, J. A., and D. J. Jude. 1980. SCUBA assessment of abundance, spawning, and behavior of fishes in southeastern Lake Michigan near the Donald C. Cook Nuclear Plant, 1975-1978. Mich. Acad. 12:345-364.

Dorr III, J.A., and T. J. Miller. 1974. Underwater operations in southeastern Lake Michigan near the Donald C. Cook Nuclear Power Plant during 1973. Pages 465-475 in E. Seibel and J. C. Ayers, eds. The biological, chemical and physical character of Lake Michigan in the vicinity of the Donald C. Cook Nuclear Plant. Spec. Rep. No. 51, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich.

Eisele, P. J., and J. F. Malaric. 1977. A conceptual model of causal factors regarding gizzard shad runs at steam electric power plants. Pages 291-298 in L. D. Jensen, ed. Fourth National Workshop on Entrainment and Impingement. Ecological Analysts, Inc., Melville, N.Y.

Emery, A. R. 1970. Fish and crayfish mortalities due to an internal seiche in Georgian Bay, Lake Huron. J. Fish. Res. Board Can. 27:1165-1168.

Foster, J. R. 1981. The efficiency of a benthic net and chain curtain in diverting fish. Pages 261-271 in P. B Dorn and J. T. Johnson, eds. Advanced intake technology for power plant cooling systems. U.S. Fish and Wildlife Service, Washington, D.C.

Freeman III, R. F., and R.K. Sharma. 1977. Survey of fish impingement at power plants in the United States: Volume II. Inland waters. Argonne National Lab. Publ. ANL/ES-56. Argonne, Ill. 328 pp.

Huang, C. K. 1969. The thermal current structure in Lake Michigan - a theoretical and observational model study. Spec. Rep. No. 43, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich.

Indiana and Michigan Power Company (IMPC). 1977. Report on the impact of cooling water use at the Donald C. Cook Nuclear Plant. Submitted to Mich. Wat. Res. Com. Ind. Mich. Power Co., Fort Wayne, Ind. 194 pp.

Indiana and Michigan Power Company (IMPC). 1979. Supplemental report demonstrating compliance with section 316(b) of the clean water act. Submitted to Mich. Wat. Res. Com. Ind. Mich. Power Co., Fort Wayne, Ind. 129 pp.

Jensen, A. L., S. A. Spigarelli, and M. M. Thommes. 1982. Use of conventional fishery models to assess entrainment and impingement of three Lake Michigan fish species. Trans. Amer. Fish. Soc. 111:21-34.

Jude, D. J., and F. J. Tesar. 1985. Recent changes in the forage fish of Lake Michigan. Can. J. Fish. Aquat. Sci. 42:1154-1157.

Jude, D. J., F. J. Tesar, J. C. Tomlinson, T. J. Miller, N. J. Thurber, G. G. Godun, and J. A. Dorr III. 1979. Inshore Lake Michigan fish populations near the D.C. Cook Nuclear Power Plant during preoperational years - 1973, 1974. Spec. Rep. No. 71, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 529 pp.

Jude, D. J., C. P. Madenjian, P. J. Schneeberger, H. T. Tin, P. J. Mansfield, T. L. Rutecki, G. E. Noguchi, and G. R. Heufelder. 1982. Adult, juvenile and larval fish populations in the vicinity of the J. H. Campbell Power Plant, 1981, with special reference to the effectiveness of wedge-wire screens in decreasing entrainment and impingement. Spec. Rep. No. 96. Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 519 pp.

Kelso, J. R. M., and C. K. Minns. 1975. Summer distribution of the nearshore fish community near a thermal generating station as determined by acoustic census. J. Fish. Res. Board Can. 32:1409-1418.

Kitchel, M. 1975. Screen monitoring study. Pages 237-260 in Operational environmental monitoring in Lake Michigan near Zion Station, July 1974 through June 1975. Vol. IV. Annual Report to Commonwealth Edison Co., Nalco Environmental Science, Northbrook, Ill.

Lifton, W. S., and J. F. Storr. 1977. The effect of environmental variables on fish impingement. Pages 299-311 in L. D. Jensen, Ed., Proceedings of the Fourth National Workshop on Entrainment and Impingement. Ecological Analysts, Inc., Melville, N.Y.

Loar, J. M., J. S. Griffith, and K. D. Kumar. 1977. An analysis of factors influencing the impingement of threadfin shad at power plants in the southeastern United States. Pages 245-255 in L. D. Jensen, ed. Fourth national workshop on Entrainment and Impingement. Ecological Analysts, Inc., Melville, N.Y.

Mortimer, C. H. 1973. Lake hydrodynamics. Mitt. Theoret. Verein. Limnol. 20:124-197.

Rago, P. J. 1979. On the calculation of production forgone due to entrainment and impingement of fishes at the Donald C. Cook Nuclear Plant. Supplemental report demonstrating compliance with section 316(b) of the clean water act. Volume I. Ind. Mich. Power Co., Fort Wayne, Ind. 129 pp.

Schneeberger, P. J., and D. J. Jude. 1981. Use of fish larva morphometry to predict exclusion capabilities of small-mesh screens at cooling-water intakes. Trans. Amer. Fish. Soc. 110:246-252.

Sharma, R. K., and R. F. Freeman. 1977. Survey of fish impingement at power plants in the United States: Volume I. The great lakes. Argonne National Laboratory publication ANL/ES-56. Argonne, Ill. 218 pp.

Stewart, D. J., J. F. Kitchell, and L. B. Crowder. 1981. Forage fish and their salmonid predators in Lake Michigan. Trans. Amer. Fish. Soc. 110:751-763.

Tesar, F. J., and D. J. Jude. 1985. Adult and juvenile fish populations of inshore southeastern Lake Michigan near the D. C. Cook Nuclear Power Plant, 1973-1982. Spec. Rep. No. 106, Great Lakes Res. Div. Univ. Mich., Ann Arbor, Mich. 94 pp.

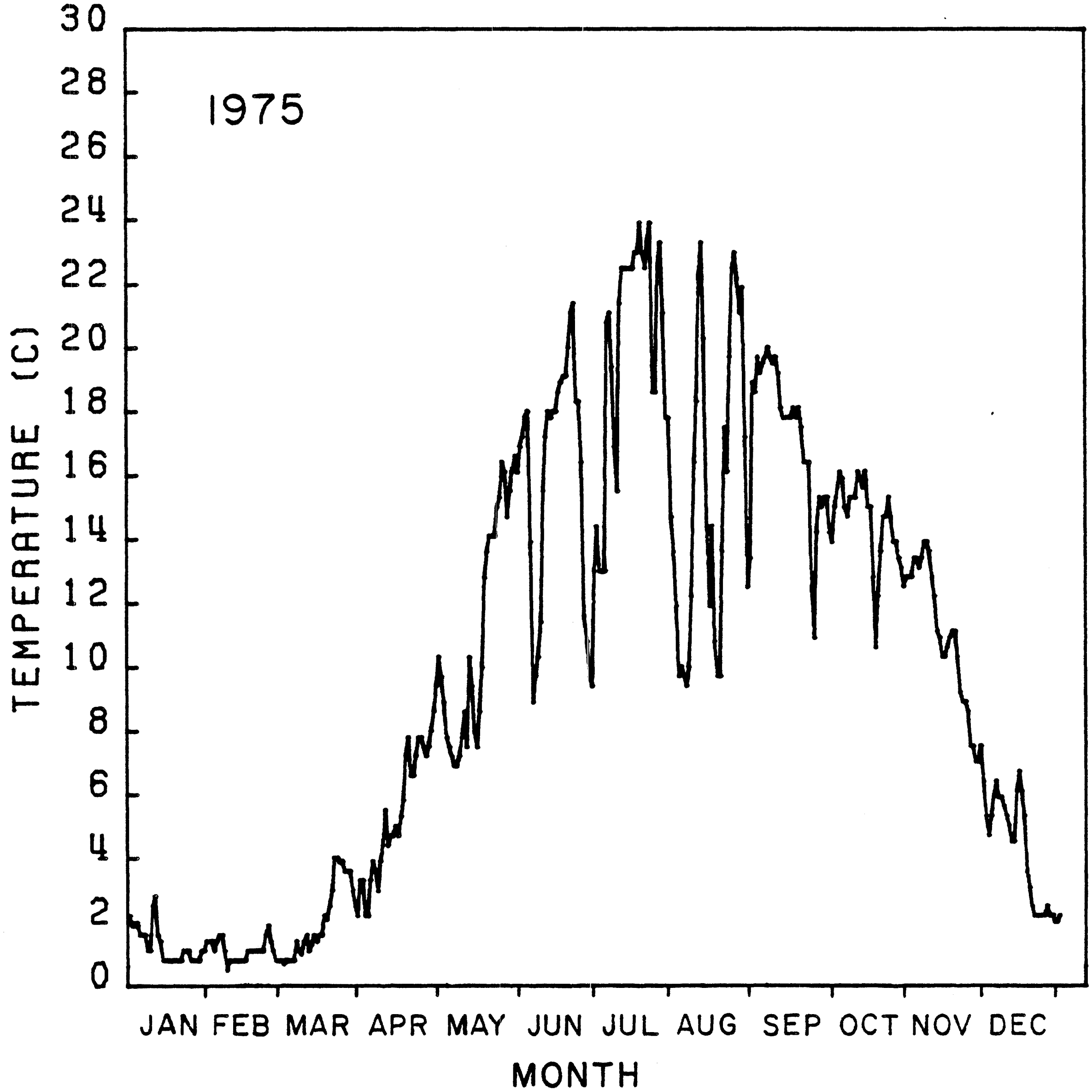
Tesar, F. J., D. Einhouse, H. T. Tin, D. L. Bimber, and D. J. Jude. 1985. Adult and juvenile fish populations near the D. C. Cook Nuclear Power Plant, southeastern Lake Michigan, during preoperational (1973-74) and operational (1975-79) years. Spec. Rep. No. 109. Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 341 pp.

Thurber, N. J., and D. J. Jude. 1984. Impingement losses at the D.C. Cook Nuclear Plant during 1975-1979 with a discussion of factors responsible and relationships to field catches. Spec. Rep. No. 104, Great Lakes Res. Div., Univ. Mich., Ann Arbor, Mich. 99 pp.

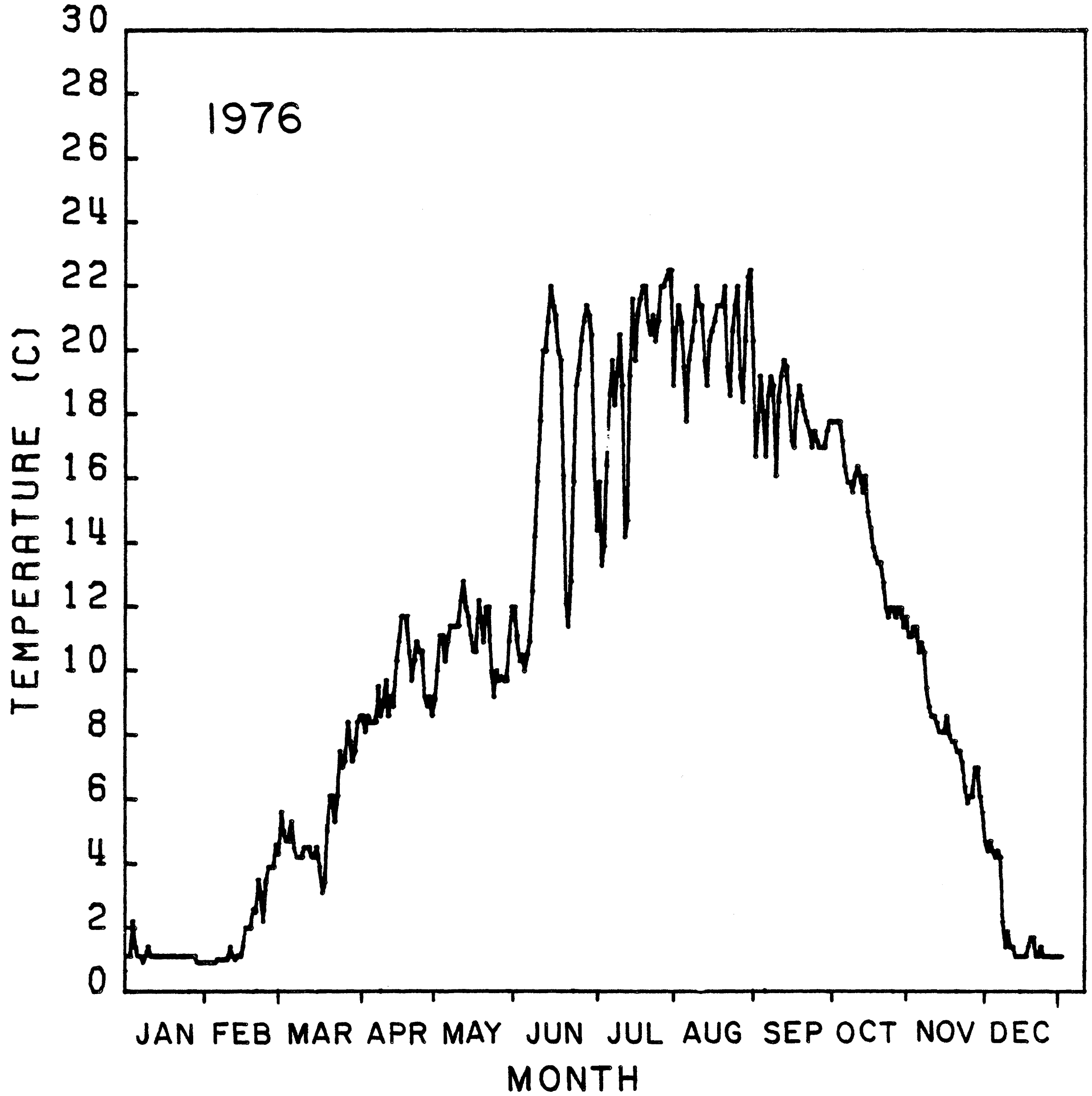
U.S. Atomic Energy Commission (USAEC). 1973. Final environmental statement related to operation of Donald C. Cook Nuclear Plant units 1 and 2. Docket nos. 50-315 and 50-316. Directorate of Licensing, U.S. Atom. Ener. Comm., Washington, D.C. 327 pp.

Wells, L. 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. Fish. Bull. 67:1-15.

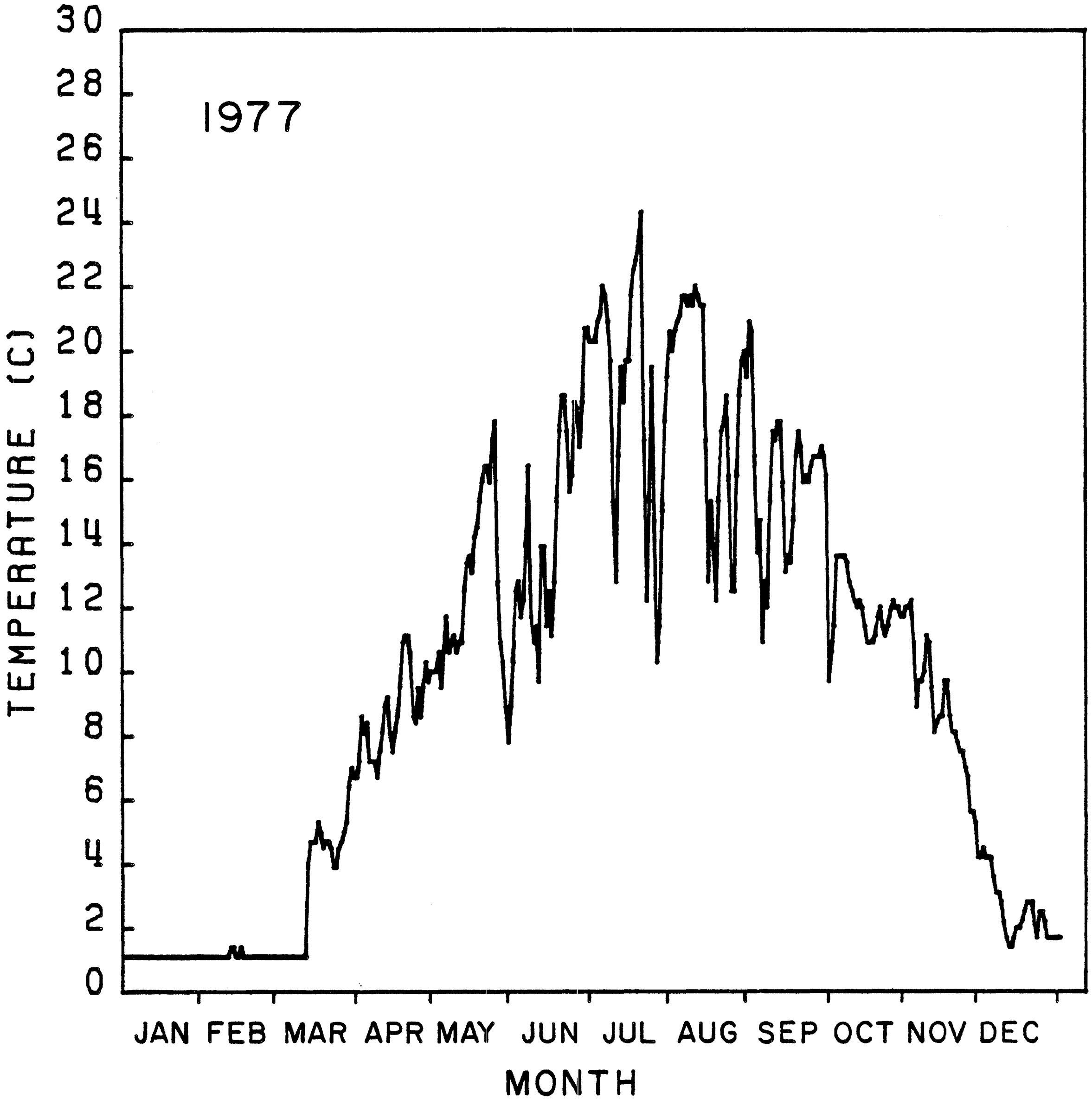
Zeitoun, I. H., J. A. Gulvas, and D. B. Roarabaugh. 1981. Effectiveness of fine mesh cylindrical wedge-wire screens in reducing entrainment of Lake Michigan ichthyoplankton. Can. J. Fish. Aquat. Sci. 38:120-125.



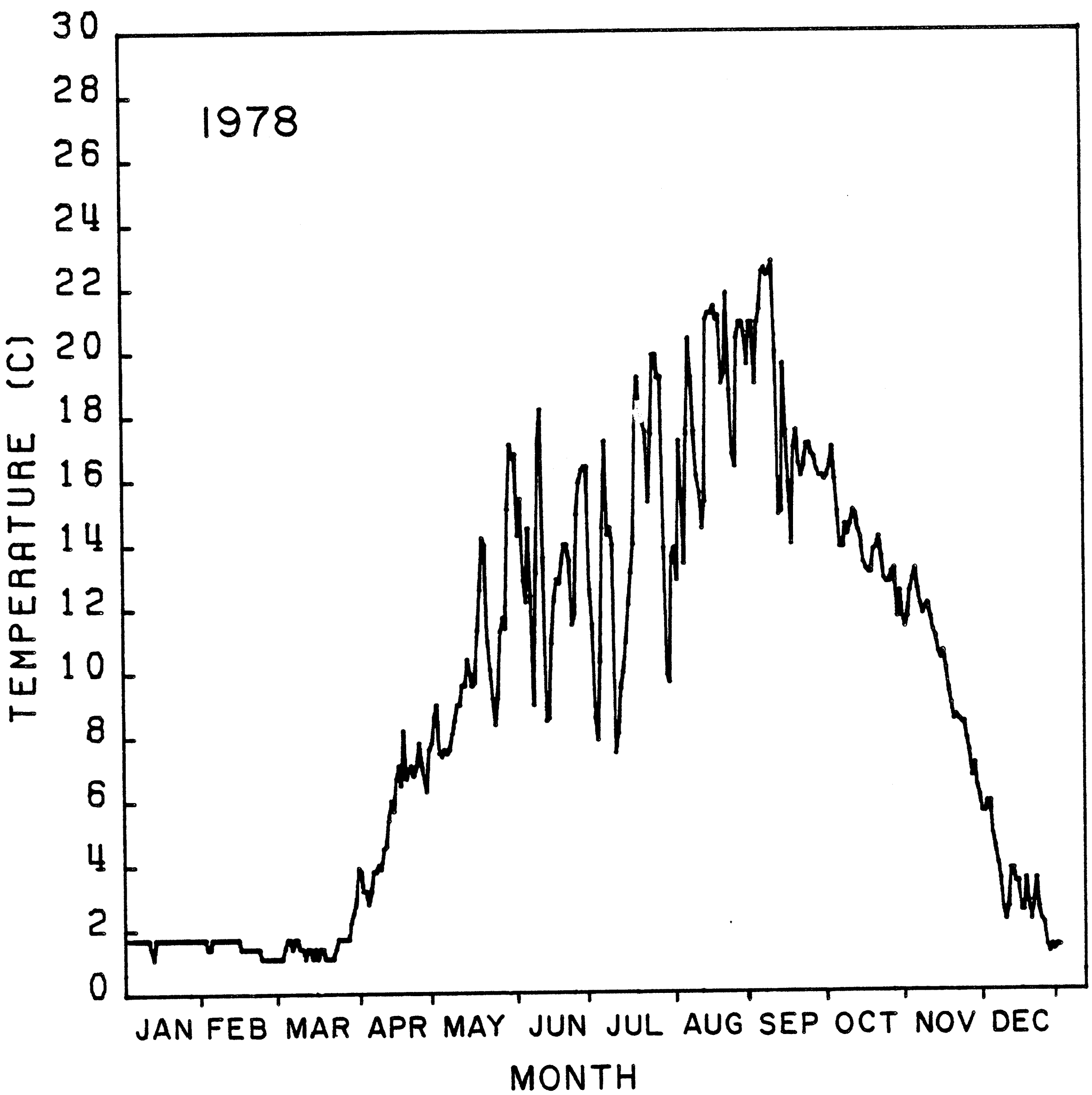
Appendix 1. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1975. Intake depth was 6 m.



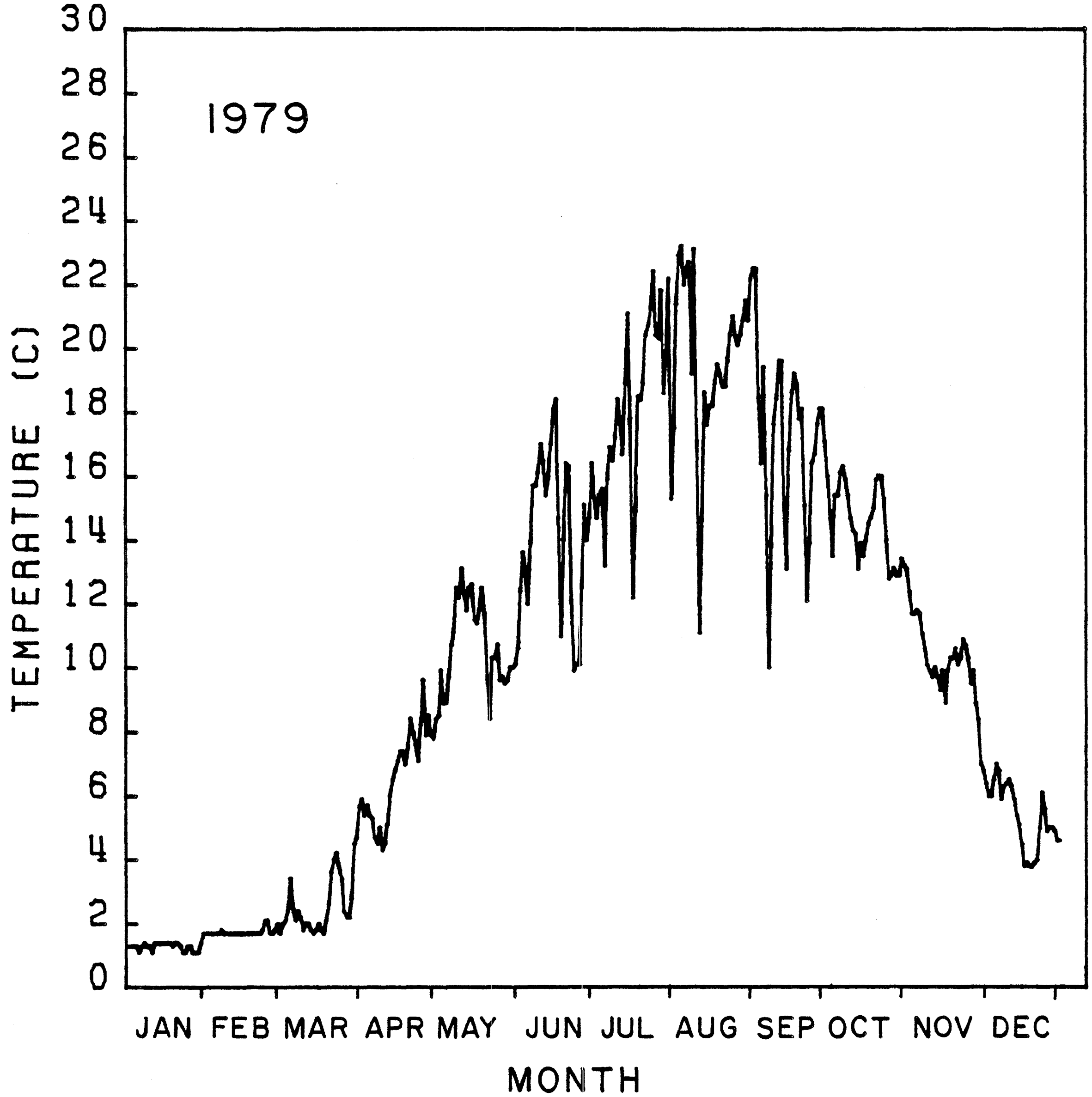
Appendix 2. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1976. Intake depth was 6 m.



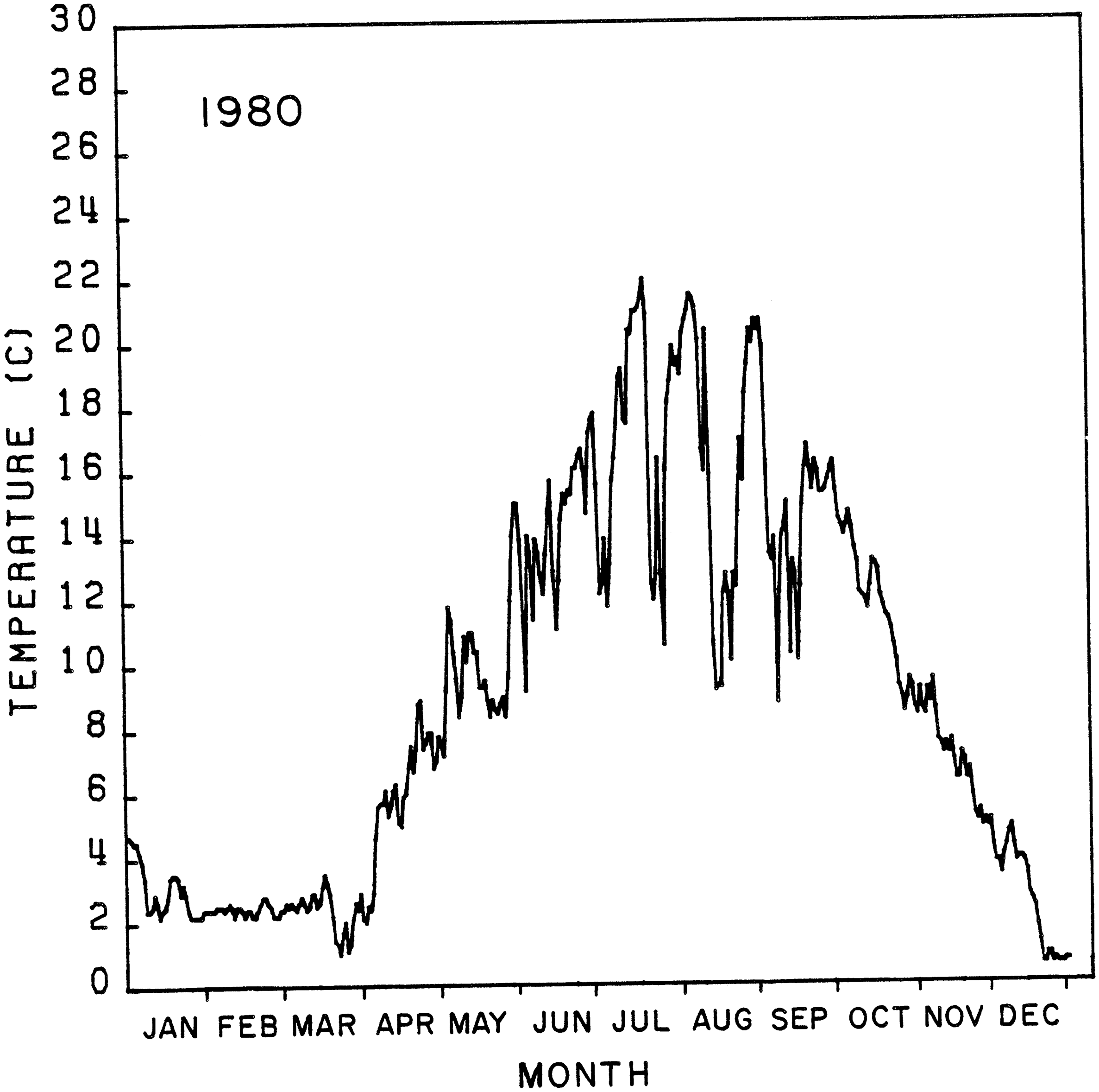
Appendix 3. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1977. Intake depth was 6 m.



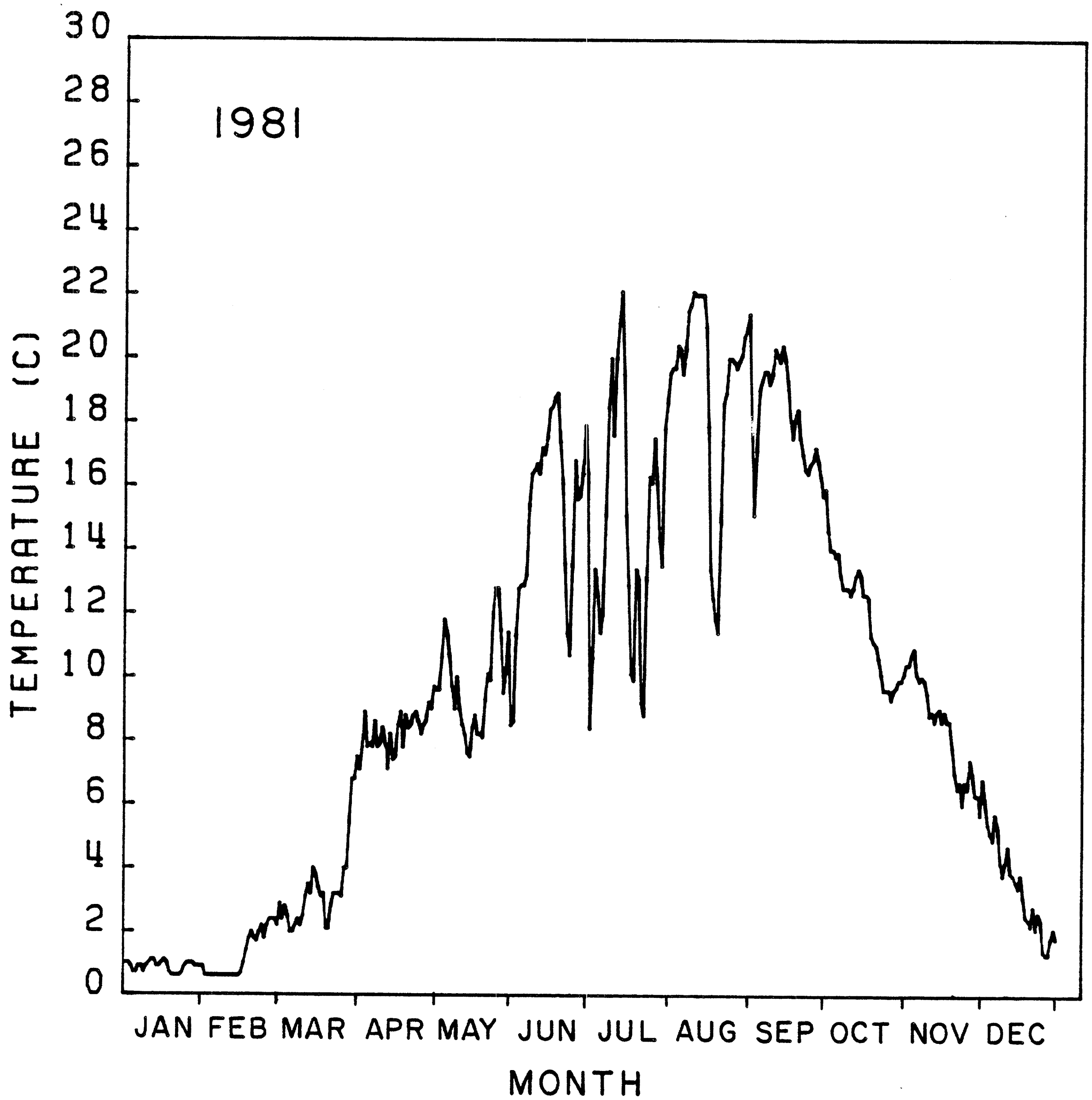
Appendix 4. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1978. Intake depth was 6 m.



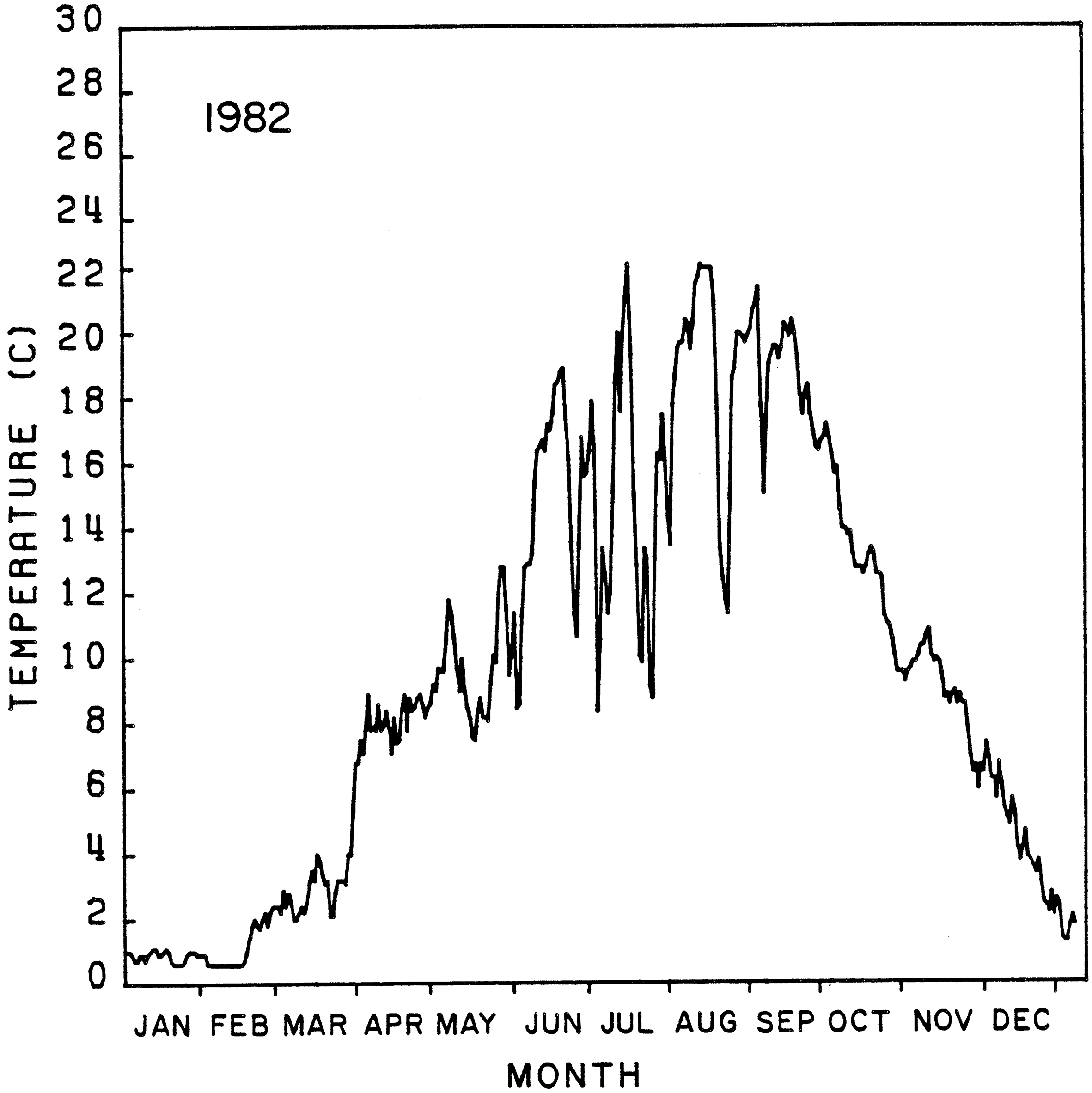
Appendix 5. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1979. Intake depth was 6 m.



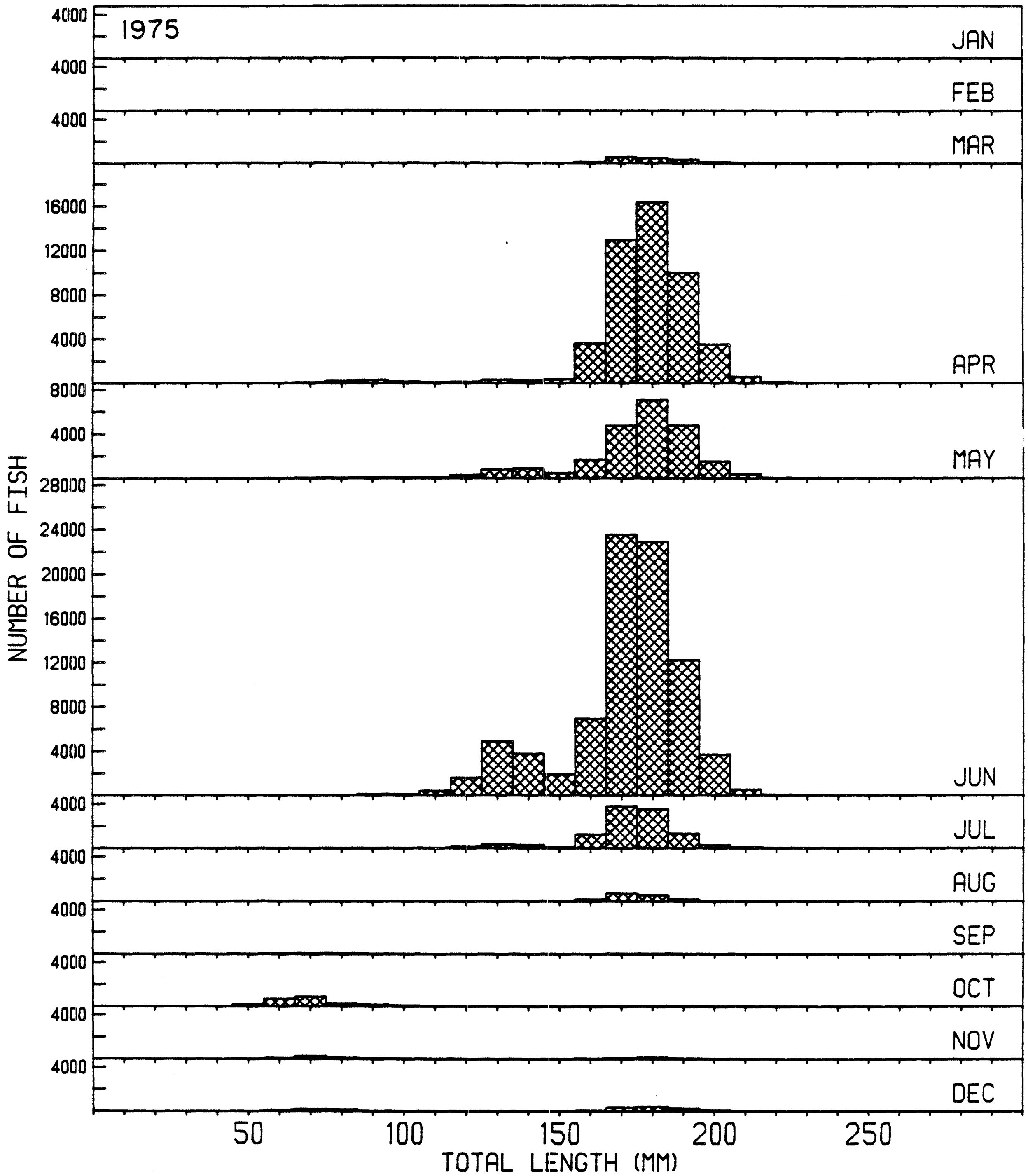
Appendix 6. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1980. Intake depth was 6 m.



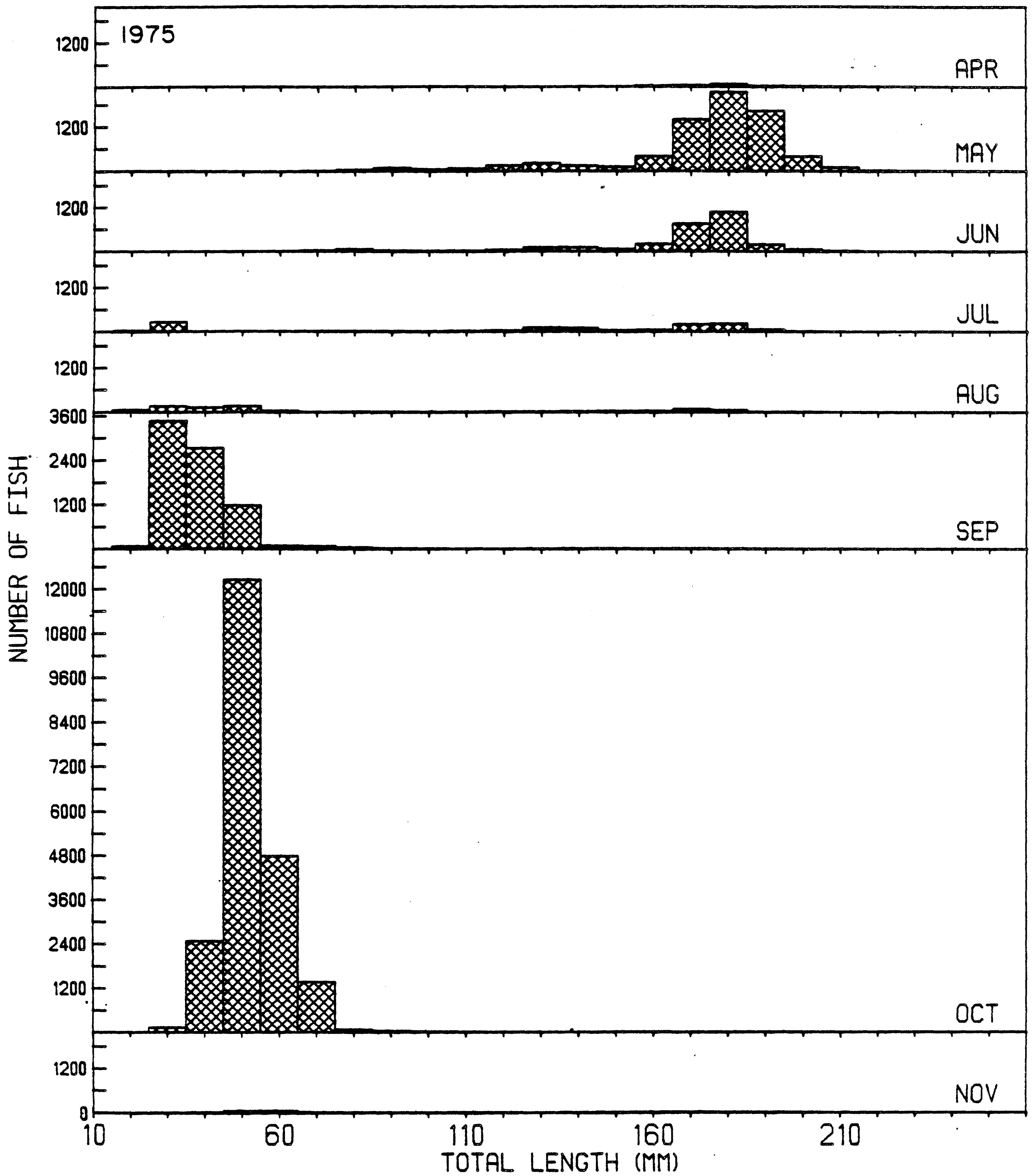
Appendix 7. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1981. Intake depth was 6 m.



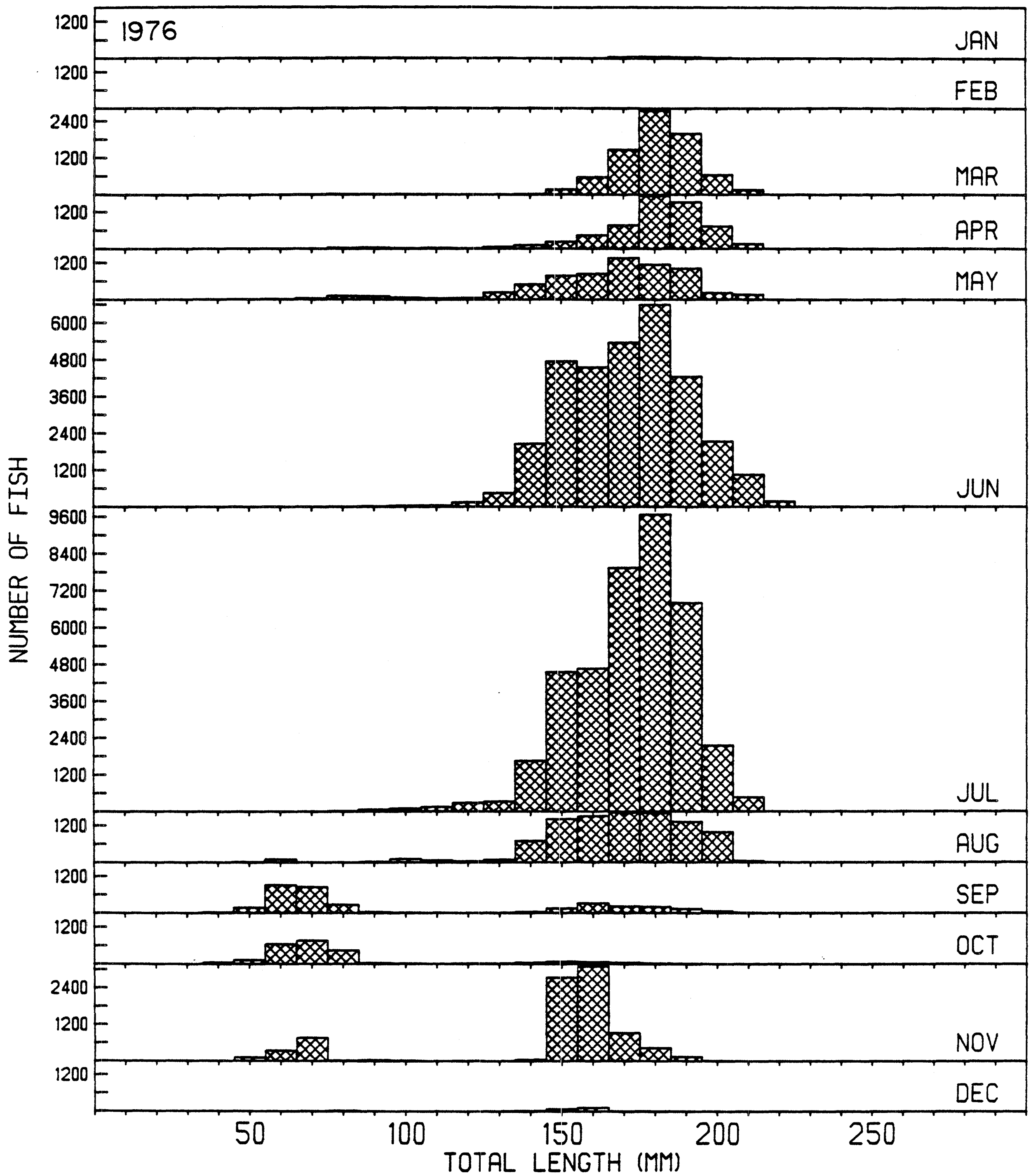
Appendix 8. Lake Michigan water temperatures recorded daily at the St. Joseph municipal water plant during 1982. Intake depth was 6 m.



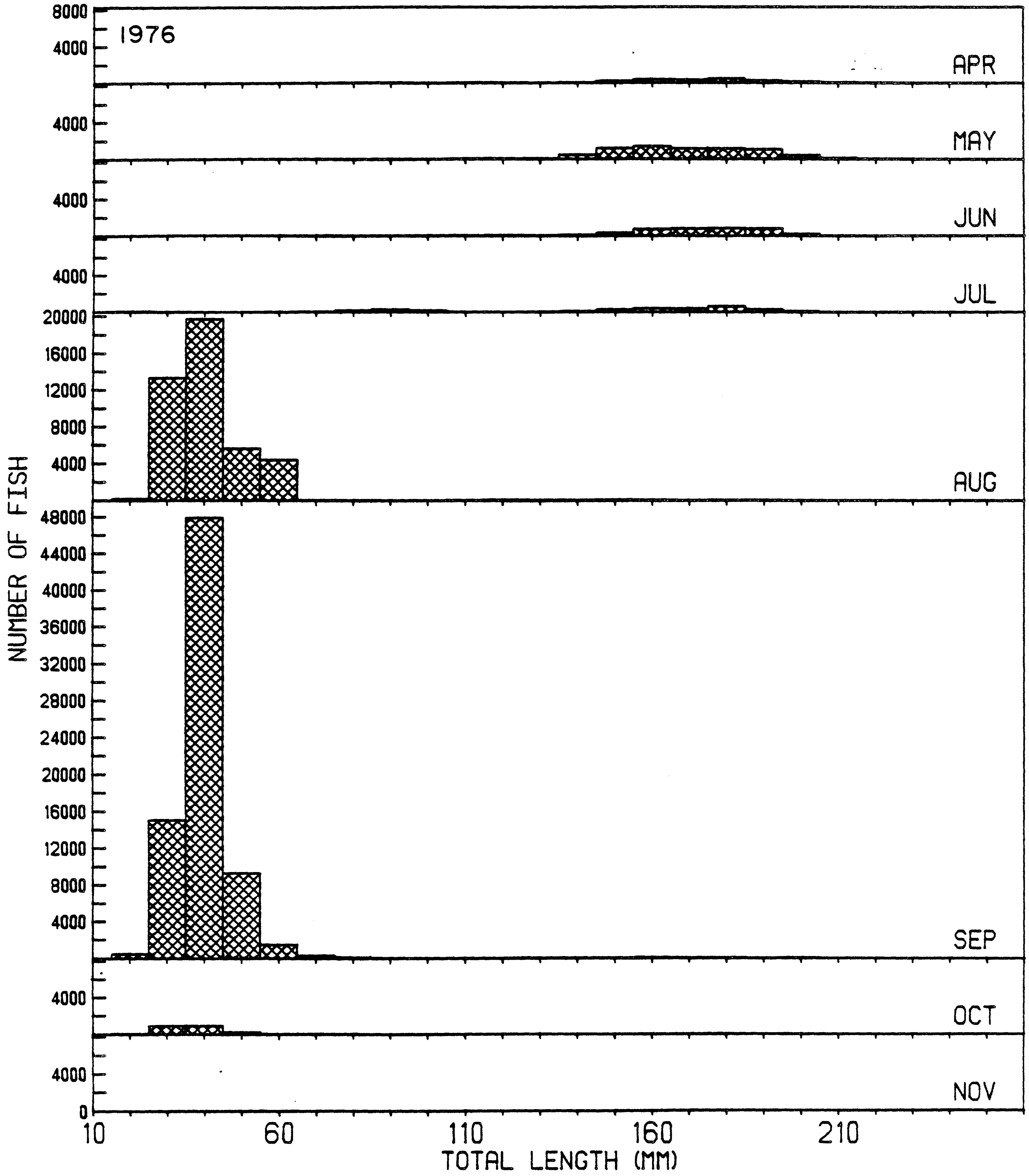
Appendix 9. Length-frequency histograms of alewives impinged during 1975 at the Cook Plant, southeastern Lake Michigan.



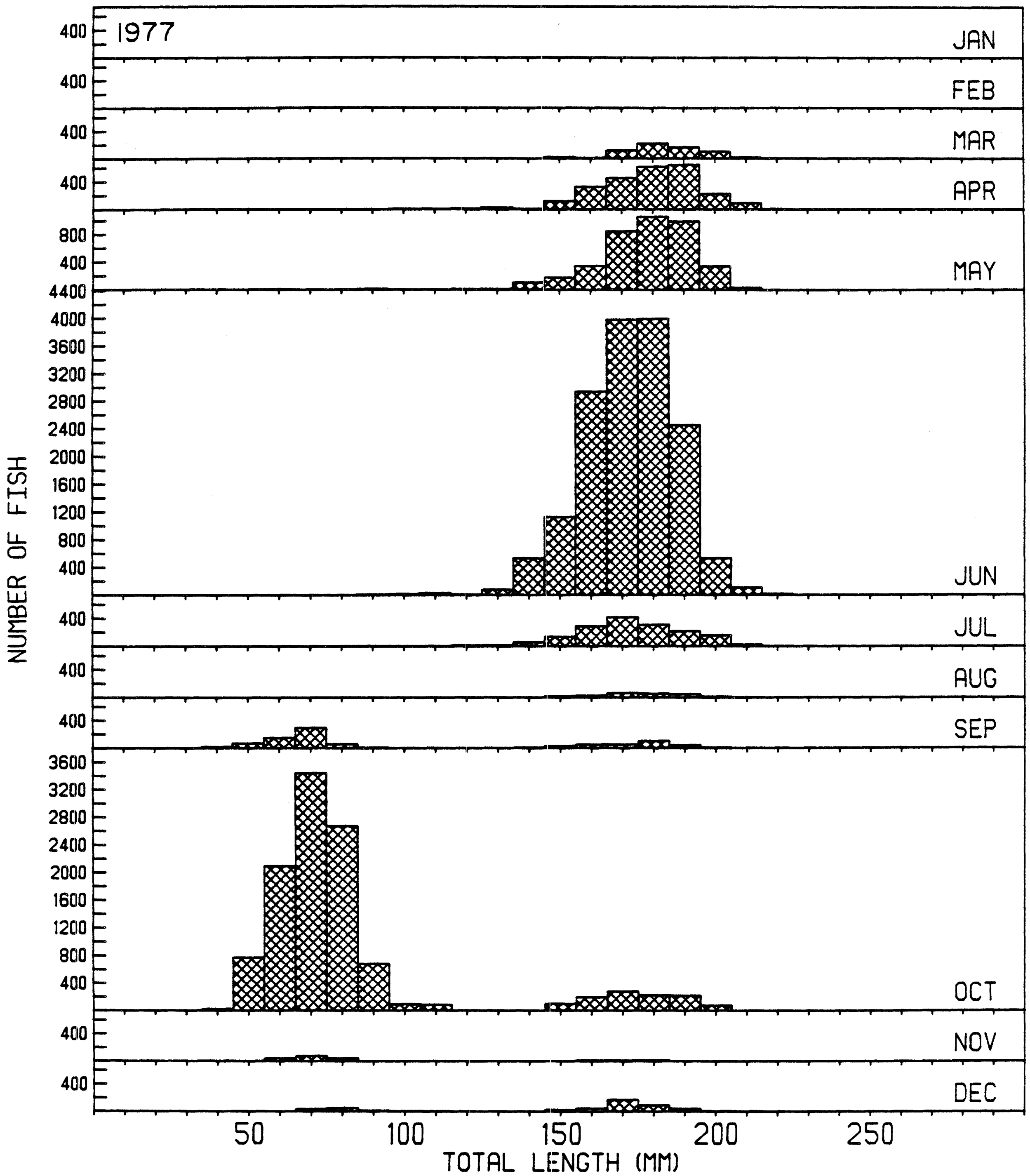
Appendix 10. Length-frequency histograms of alewives caught during 1975 field sampling at the Cook Plant, southeastern Lake Michigan.



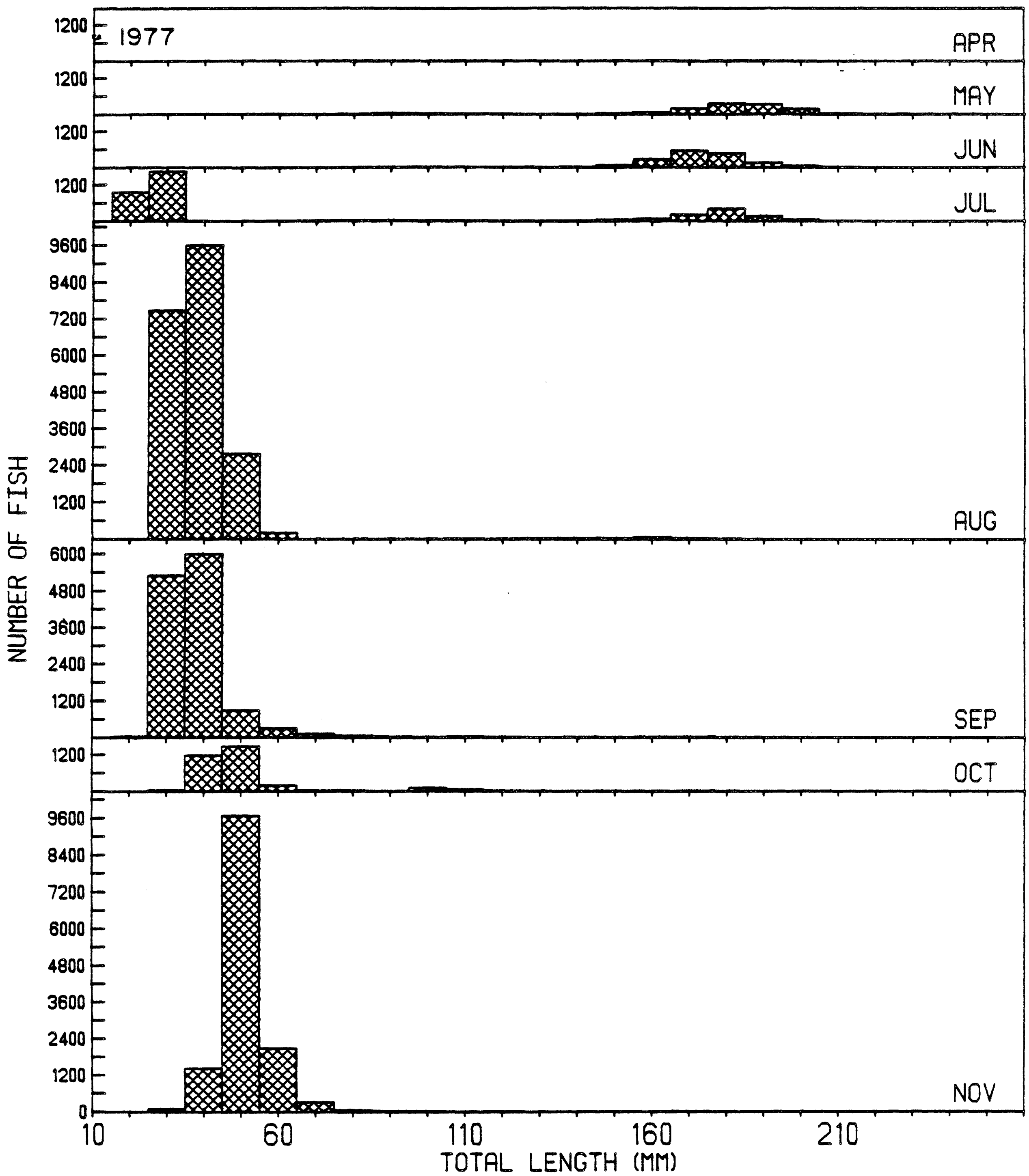
Appendix 11. Length-frequency histograms of alewives impinged during 1976 at the Cook Plant, southeastern Lake Michigan.



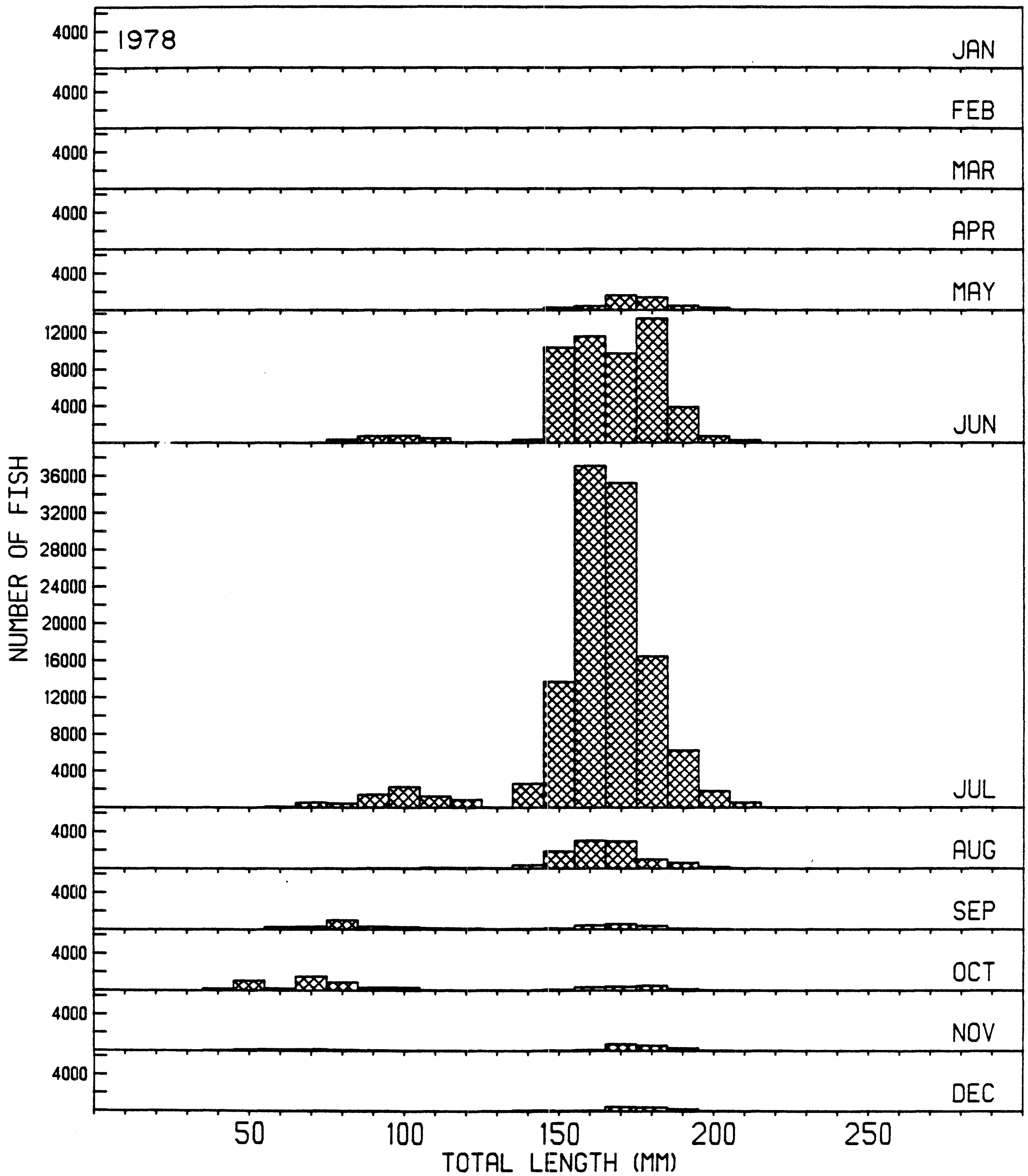
Appendix 12. Length-frequency histograms of alewives caught during 1976 field sampling at the Cook Plant, southeastern Lake Michigan.



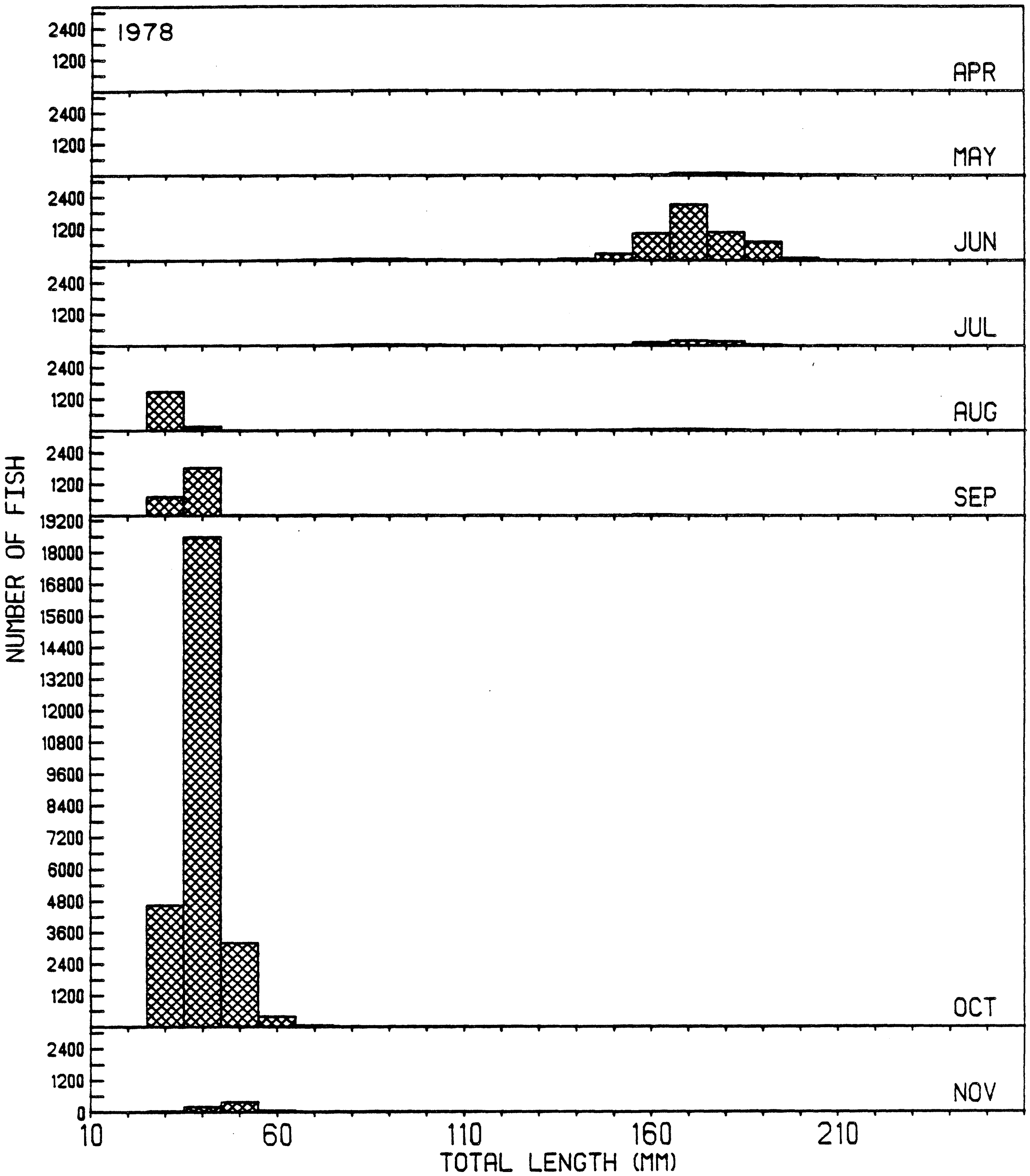
Appendix 13. Length-frequency histograms of alewives impinged during 1977 at the Cook Plant, southeastern Lake Michigan.



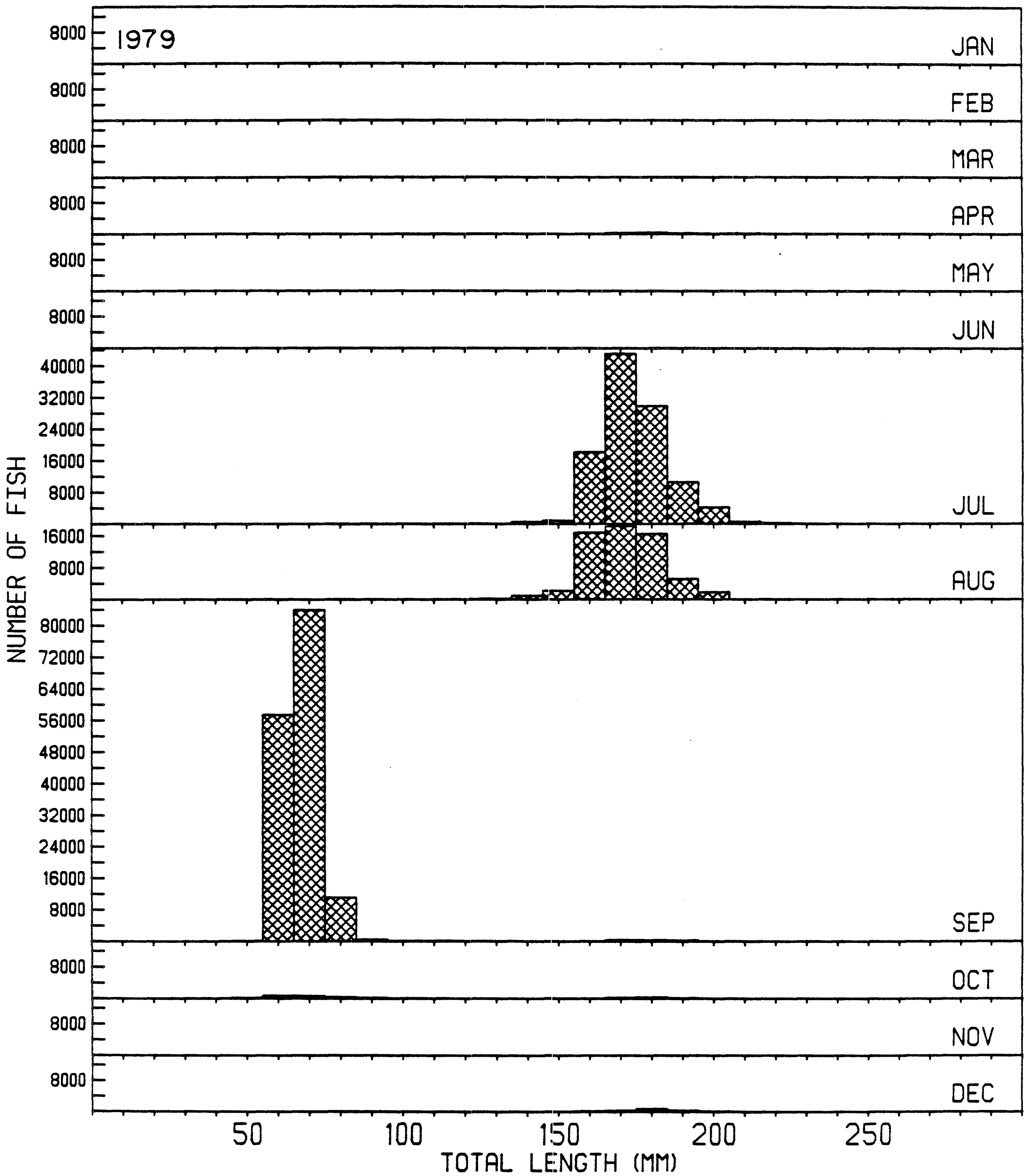
Appendix 14. Length-frequency histograms of alewives caught during 1977 field sampling at the Cook Plant, southeastern Lake Michigan.



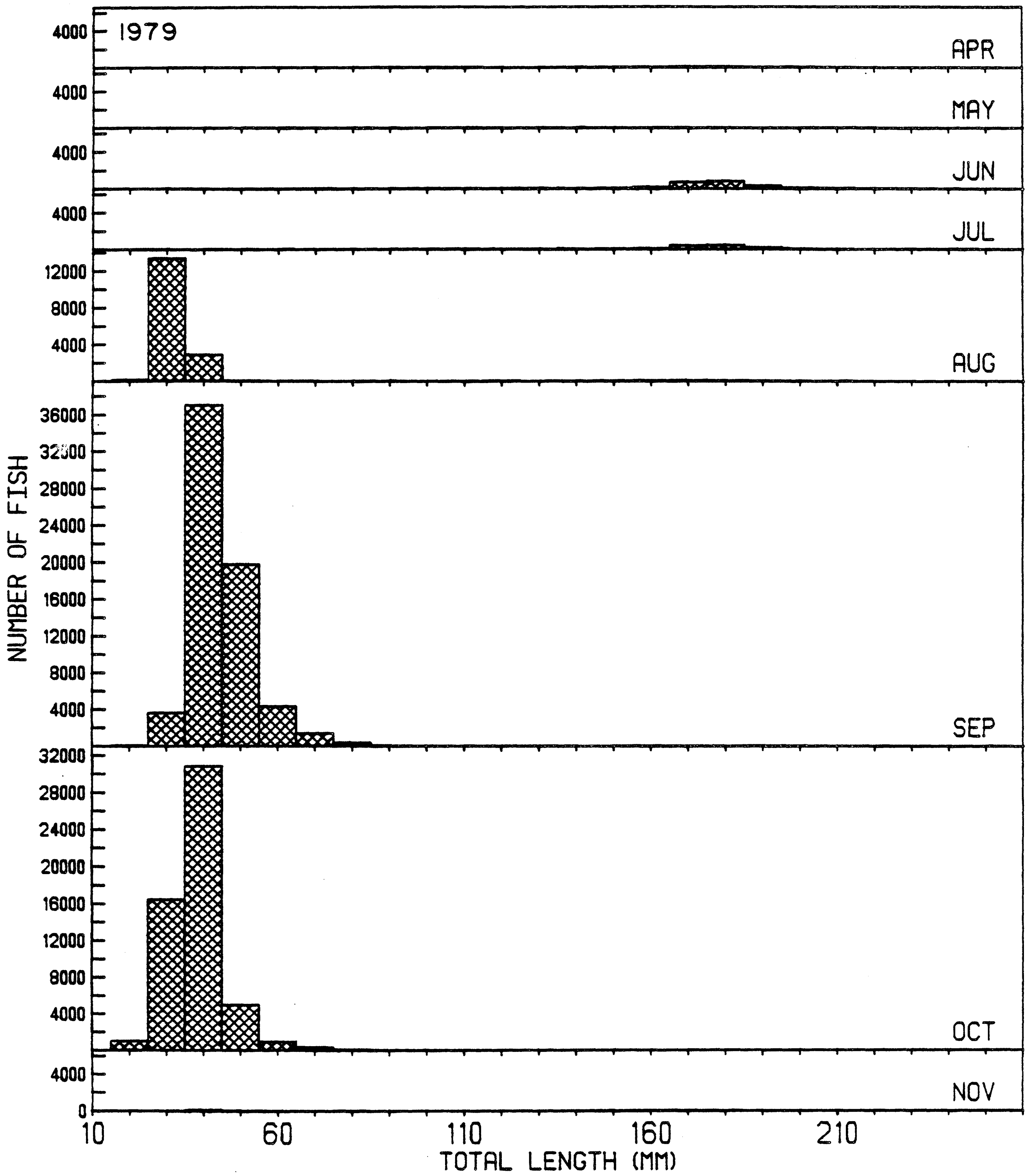
Appendix 15. Length-frequency histograms of alewives impinged during 1978 at the Cook Plant, southeastern Lake Michigan.



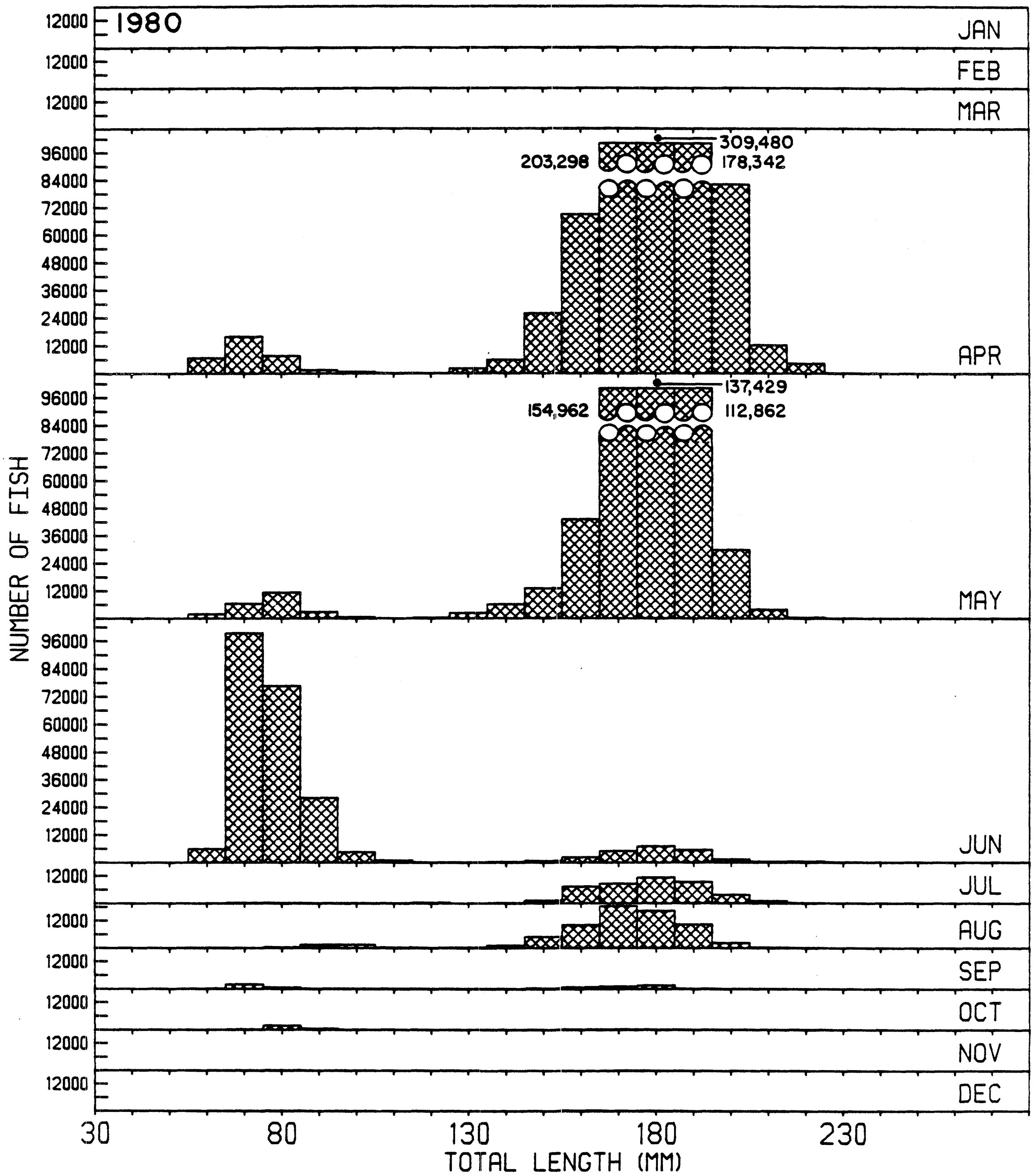
Appendix 16. Length-frequency histograms of alewives caught during 1978 field sampling at the Cook Plant, southeastern Lake Michigan.



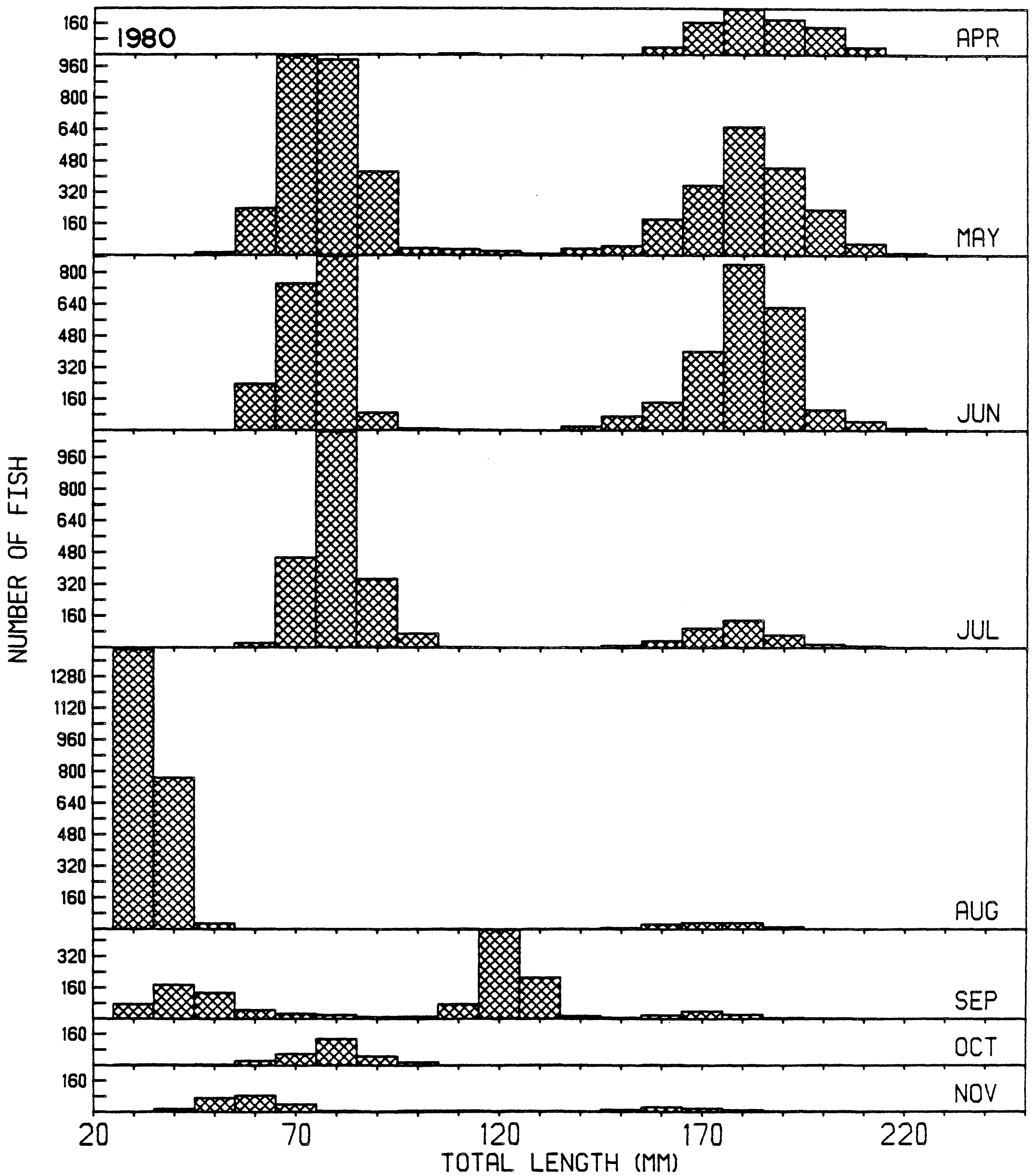
Appendix 17. Length-frequency histograms of alewives impinged during 1979 at the Cook Plant, southeastern Lake Michigan.



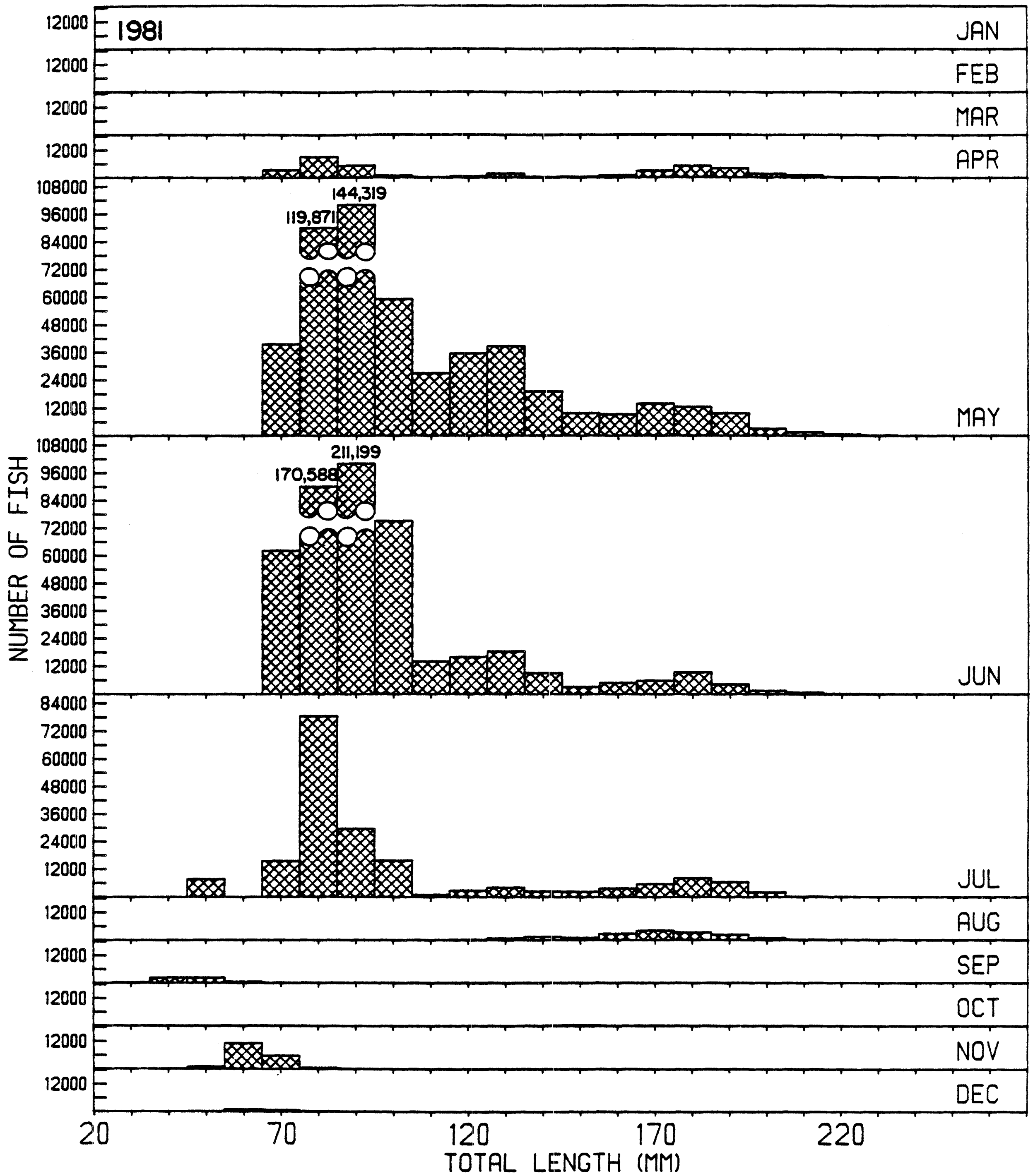
Appendix 18. Length-frequency histograms of alewives caught during 1979 field sampling at the Cook Plant, southeastern Lake Michigan.



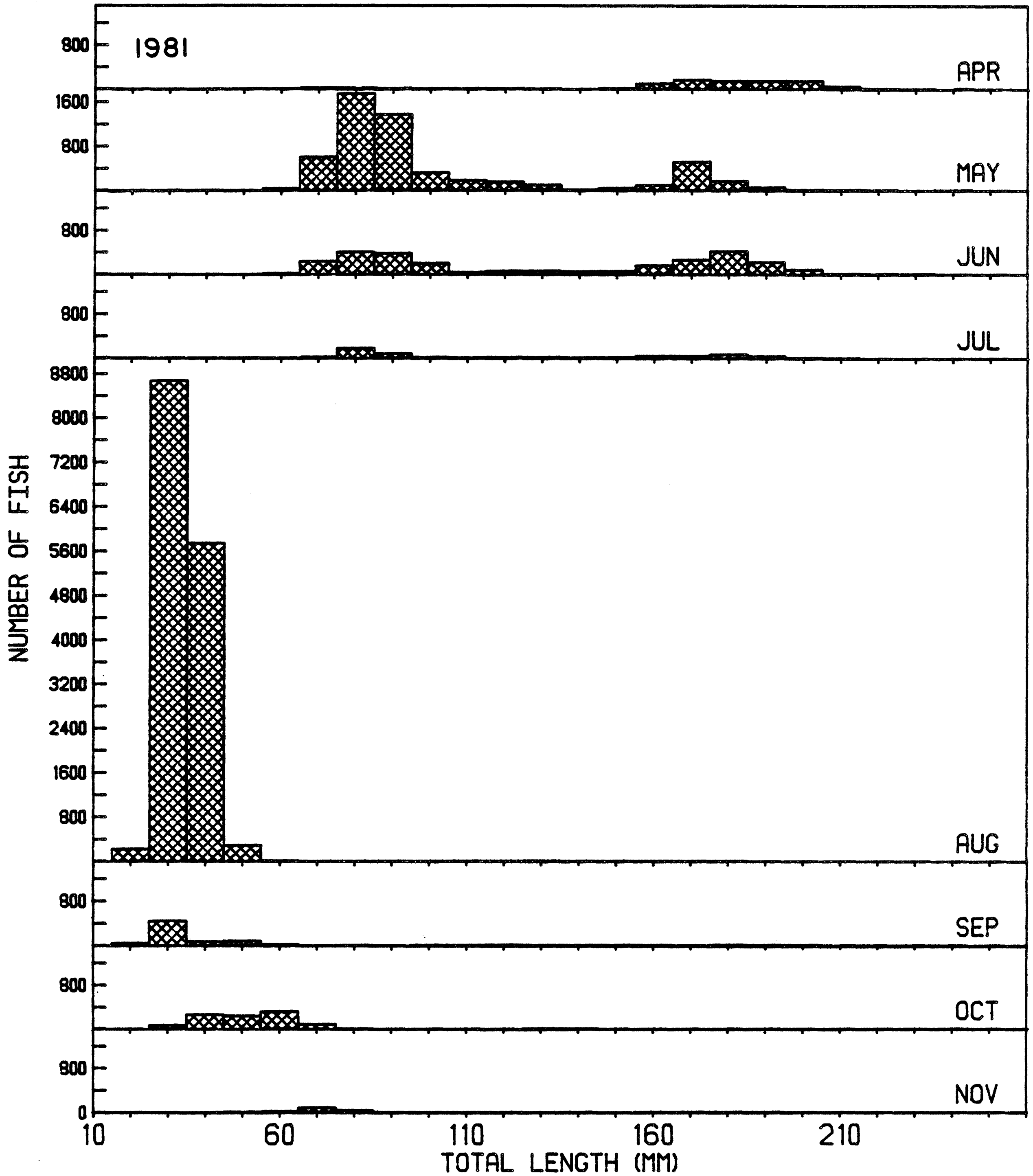
Appendix 19. Length-frequency histograms of alewives impinged during 1980 at the Cook Plant, southeastern Lake Michigan.



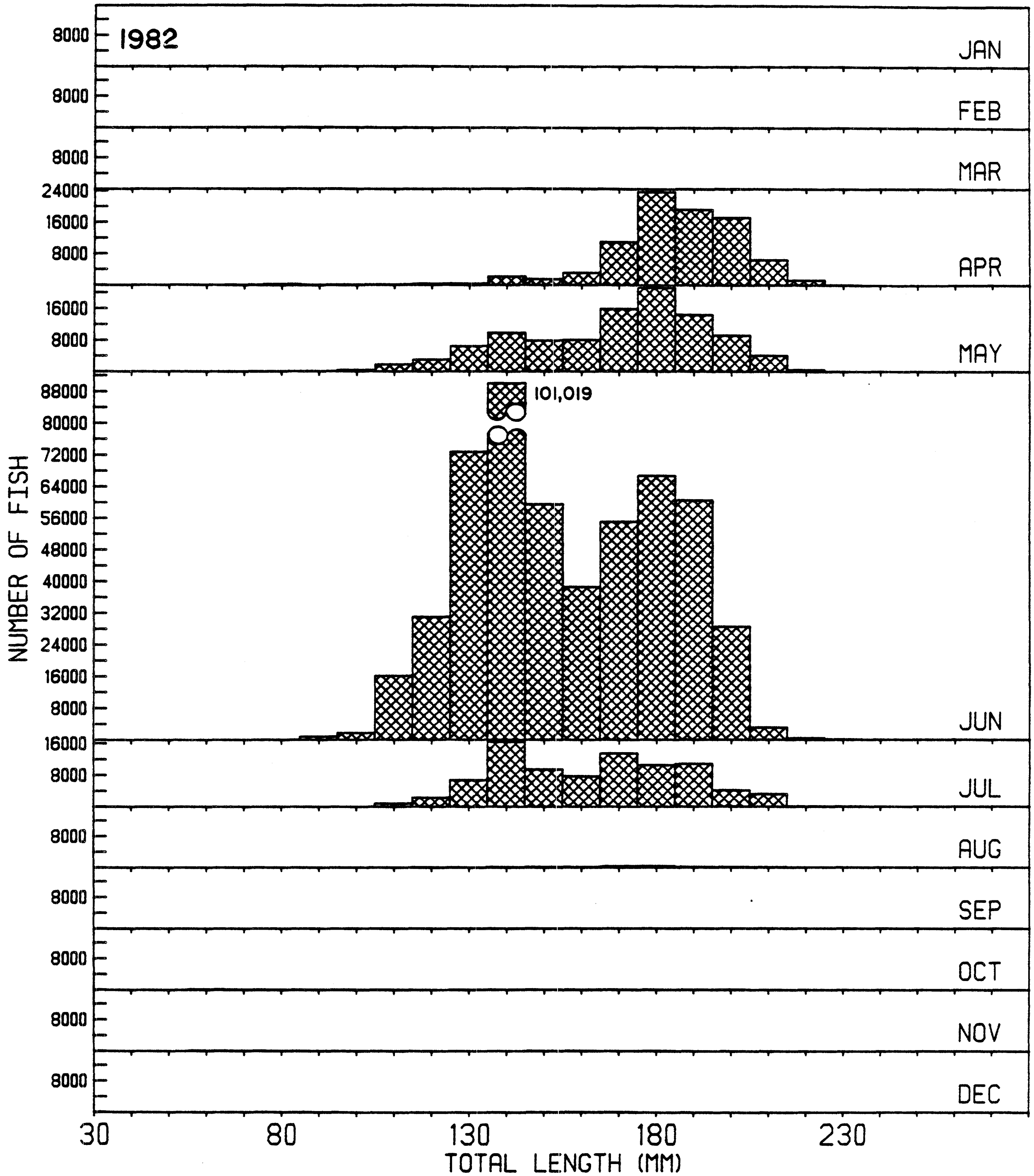
Appendix 20. Length-frequency histograms of alewives caught during 1980 field sampling at the Cook Plant, southeastern Lake Michigan.



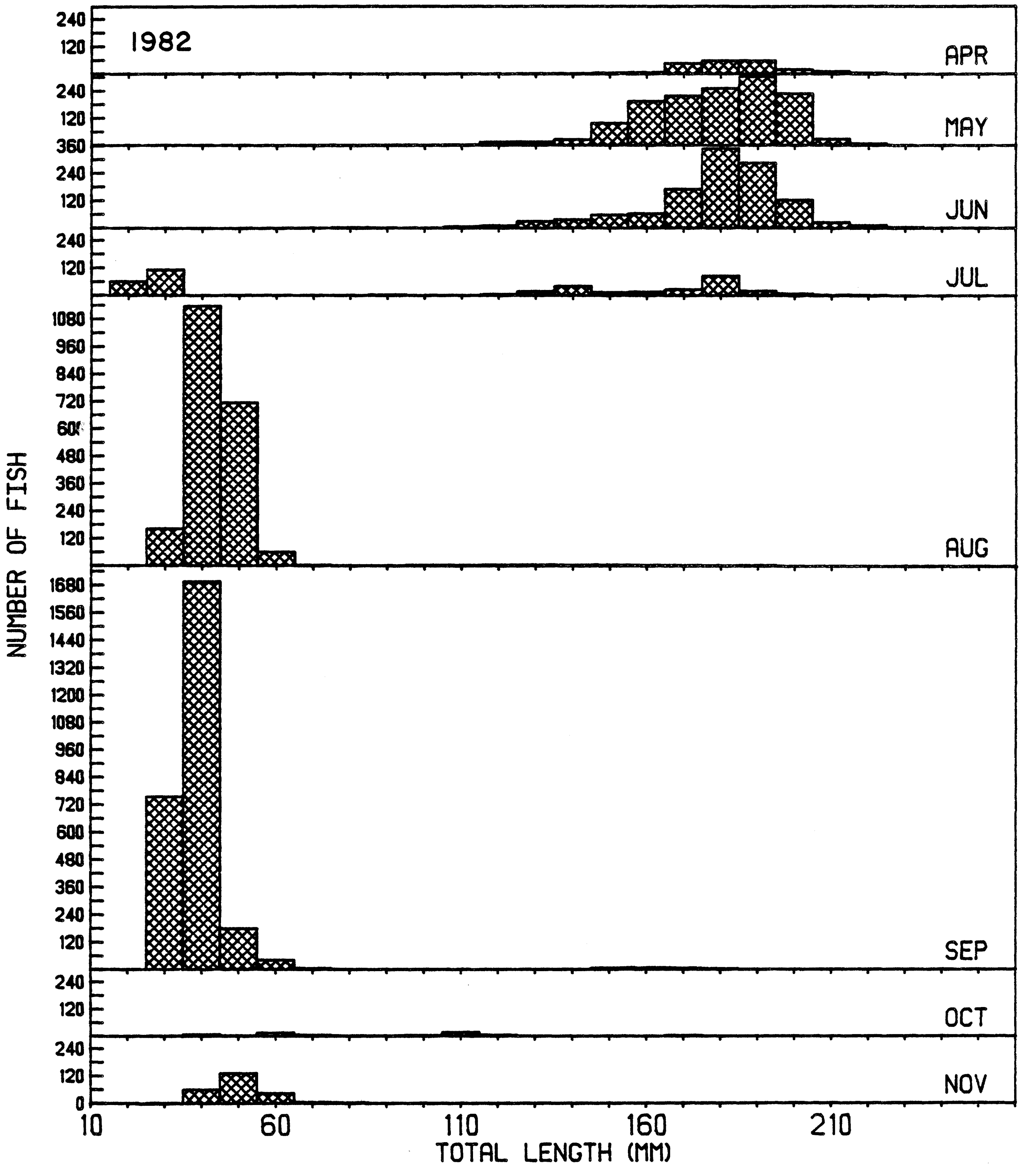
Appendix 21. Length-frequency histograms of alewives impinged during 1981 at the Cook Plant, southeastern Lake Michigan.



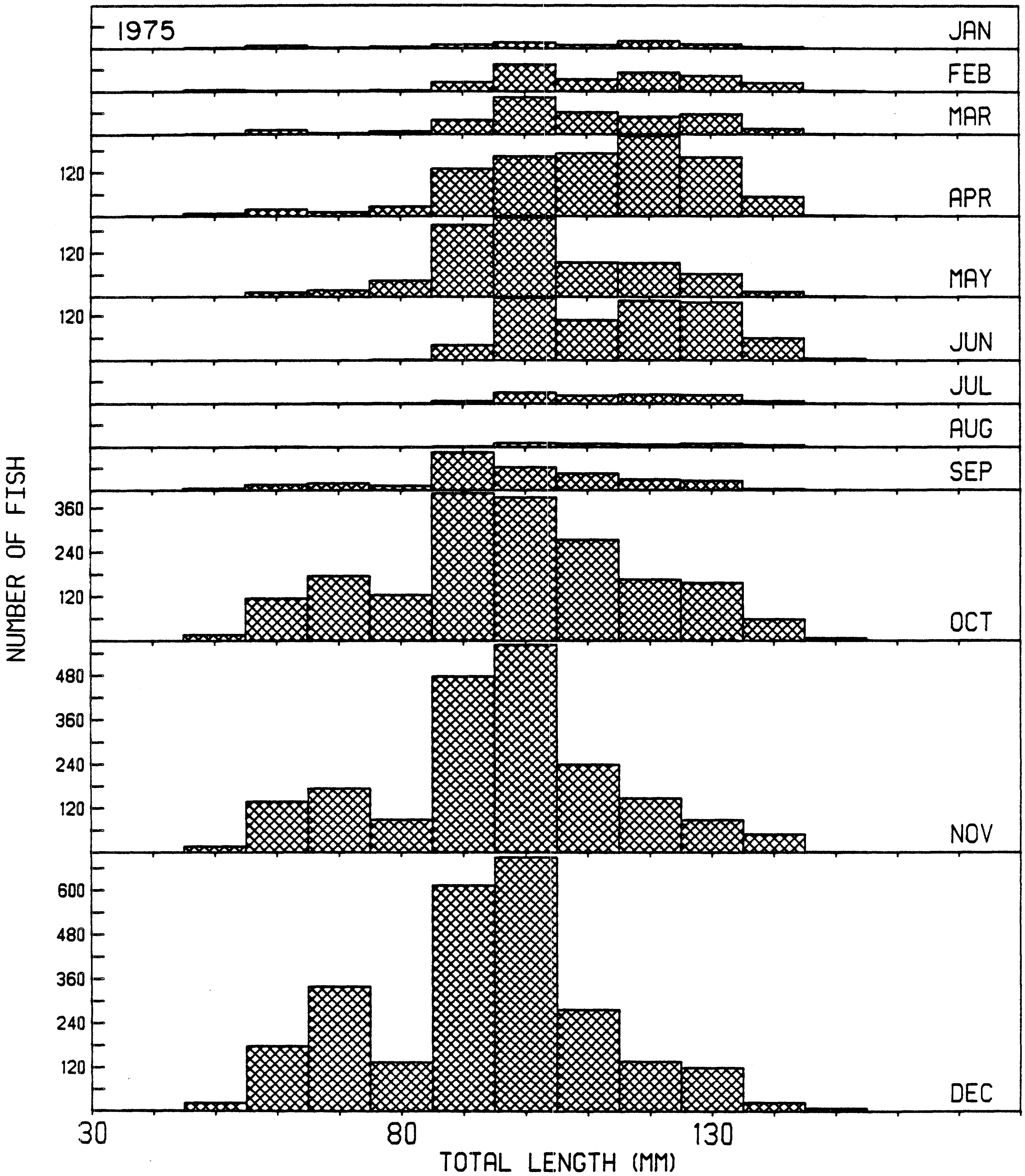
Appendix 22. Length-frequency histograms of alewives caught during 1981 field sampling at the Cook Plant, southeastern Lake Michigan.



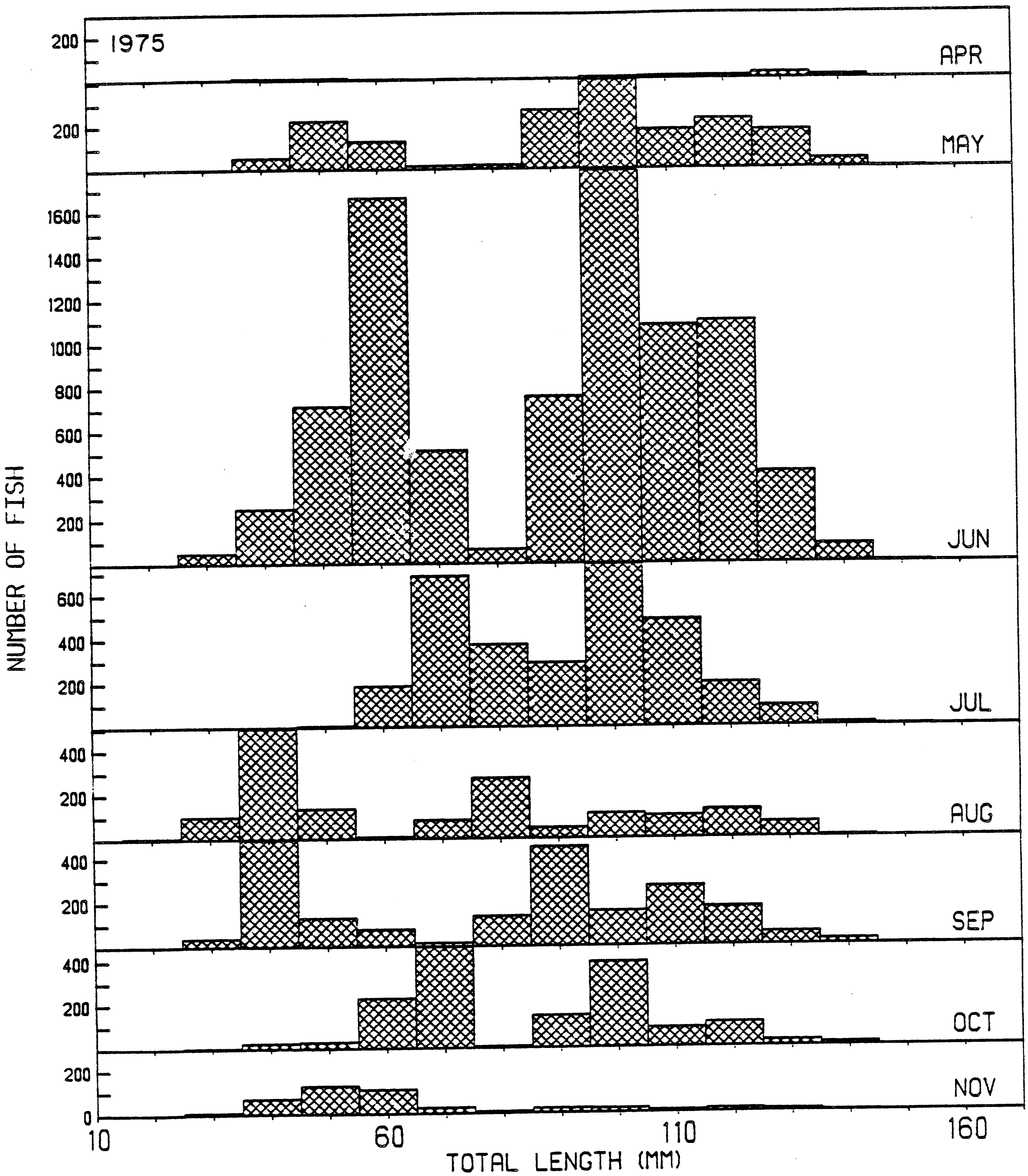
Appendix 23. Length-frequency histograms of alewives impinged during 1982 at the Cook Plant, southeastern Lake Michigan.



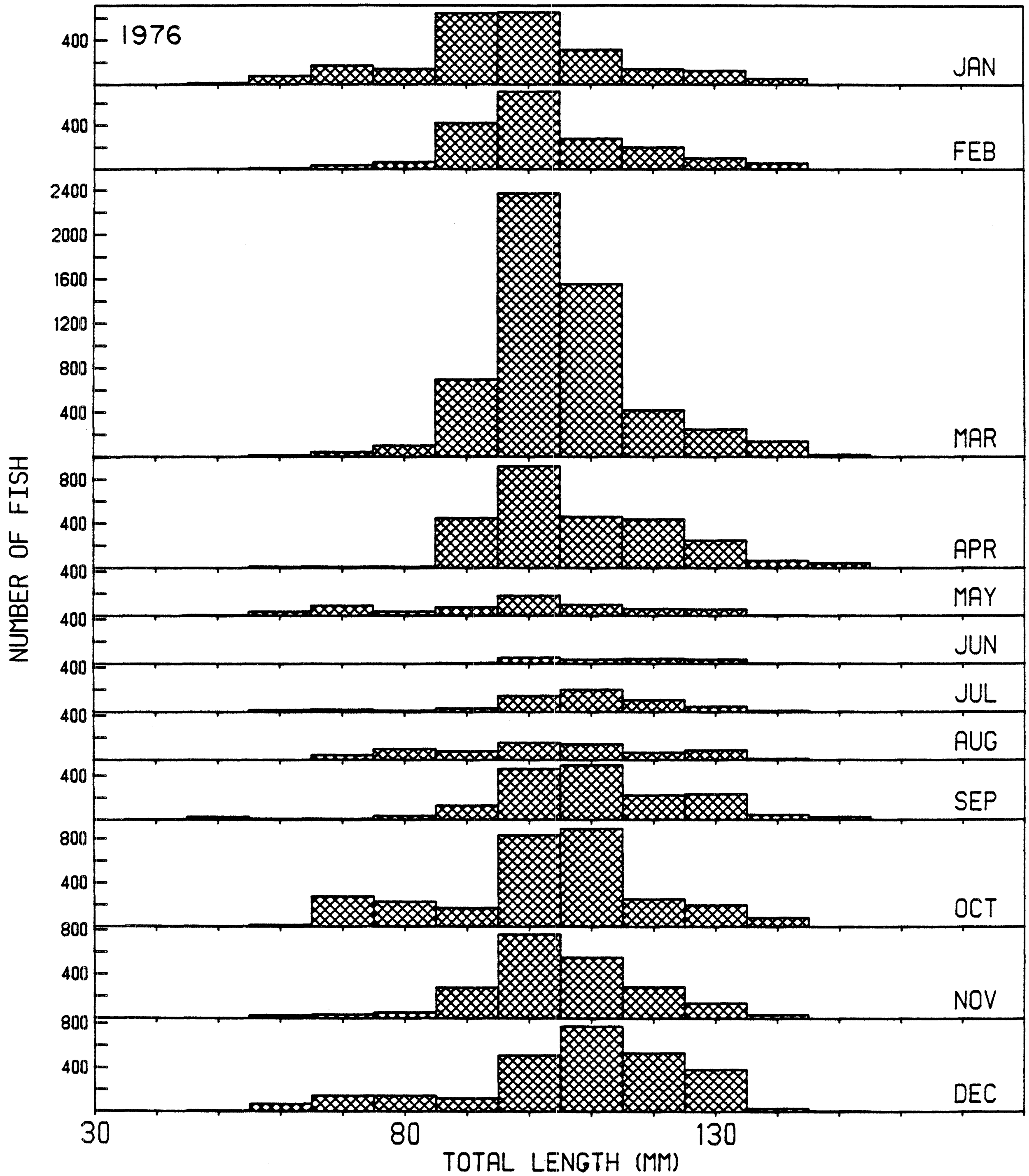
Appendix 24. Length-frequency histograms of alewives caught during 1982 field sampling at the Cook Plant, southeastern Lake Michigan.



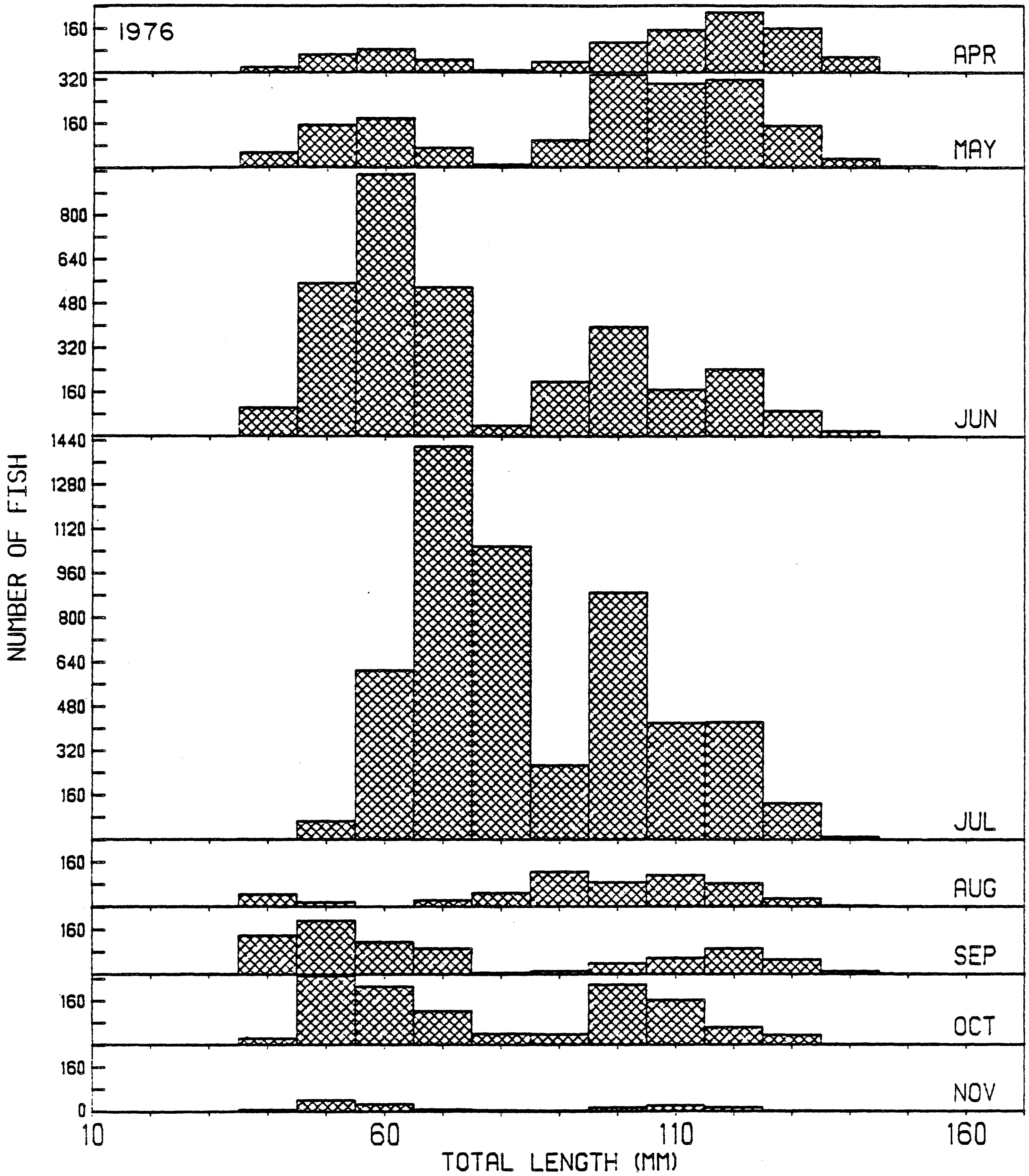
Appendix 25. Length-frequency histograms of spottail shiners impinged during 1975 at the Cook Plant, southeastern Lake Michigan.



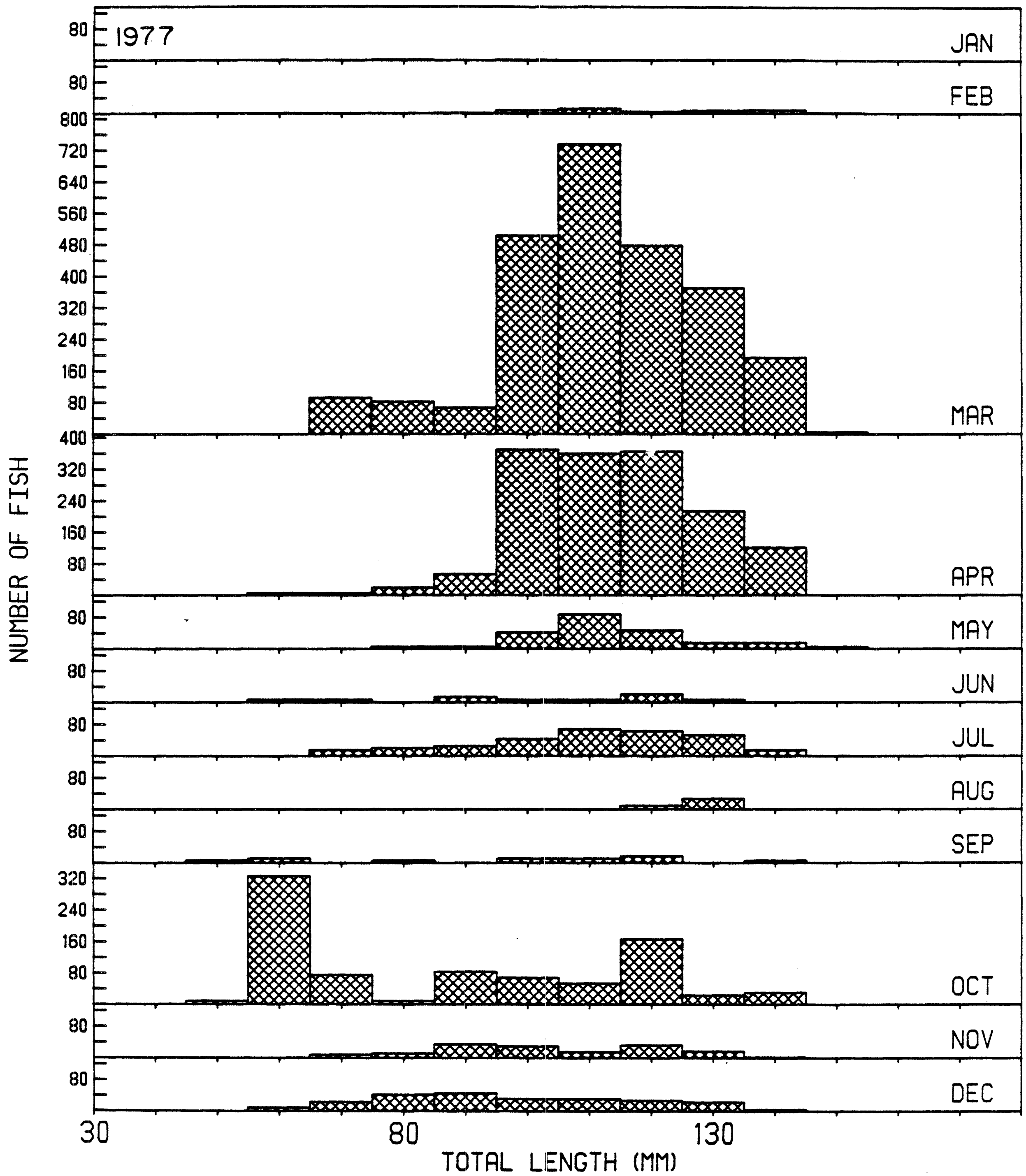
Appendix 26. Length-frequency histograms of spottail shiners caught during 1975 field sampling at the Cook Plant, southeastern Lake Michigan.



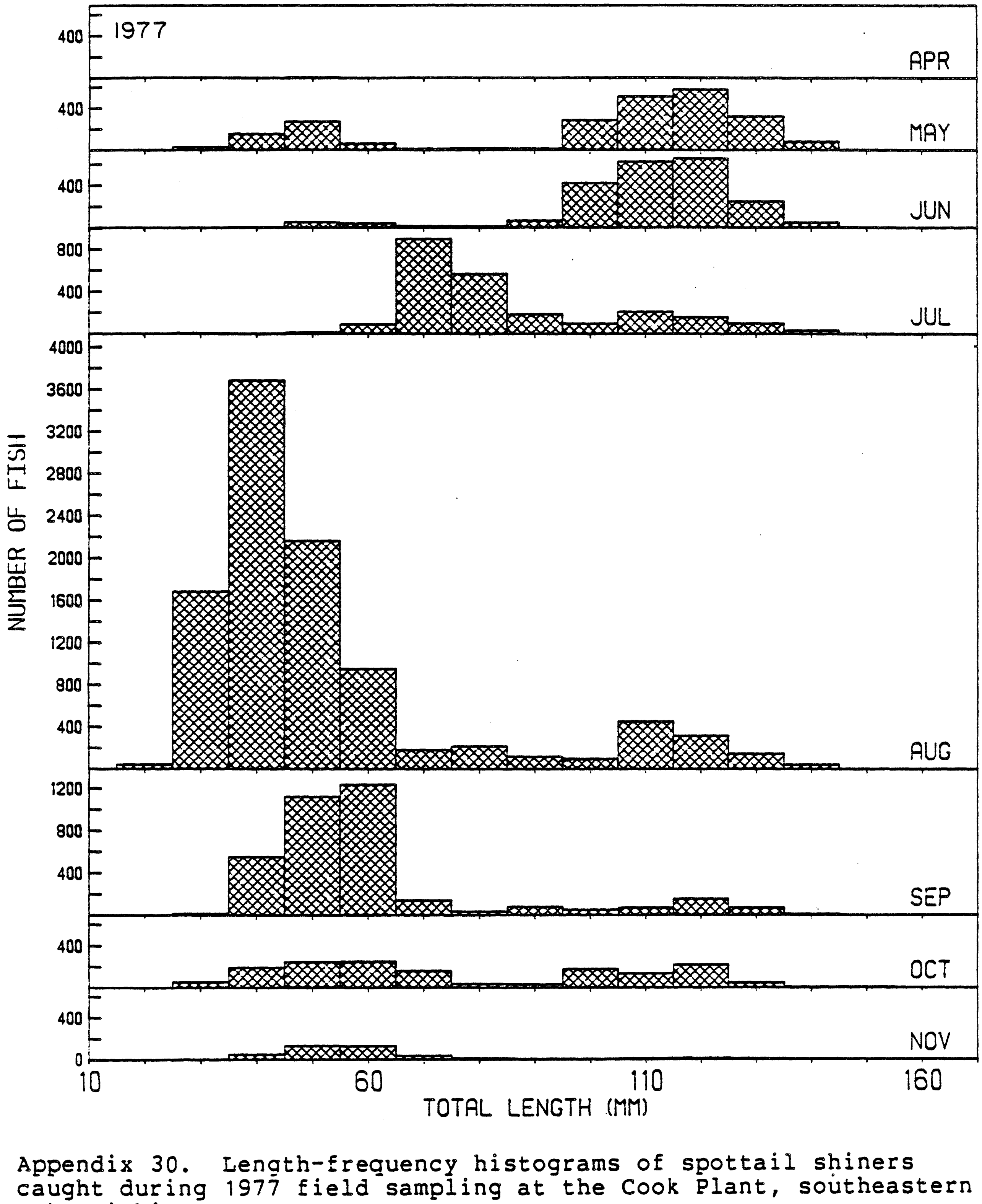
Appendix 27. Length-frequency histograms of spottail shiners impinged during 1976 at the Cook Plant, southeastern Lake Michigan.



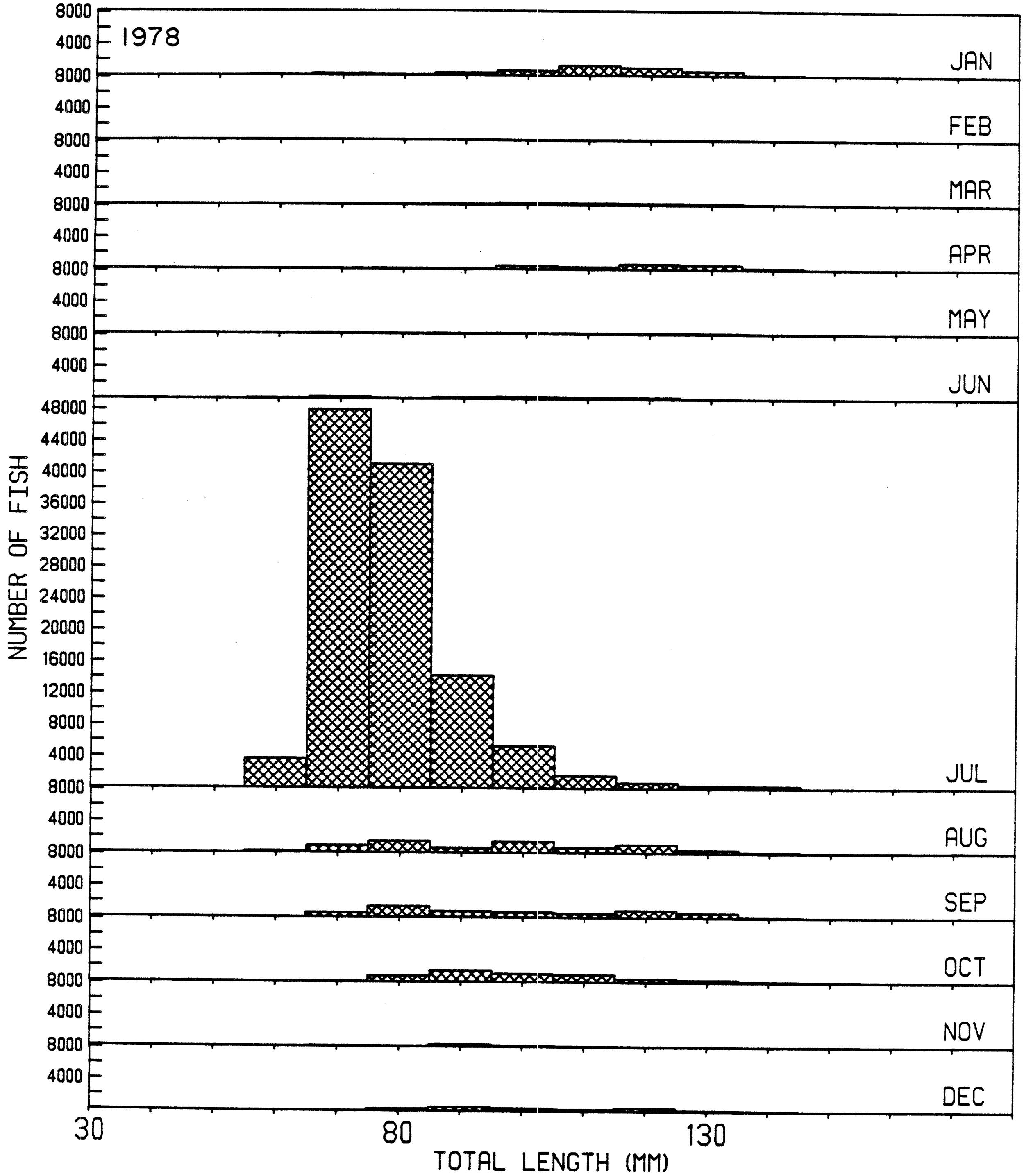
Appendix 28. Length-frequency histograms of spottail shiners caught during 1976 field sampling at the Cook Plant, southeastern Lake Michigan.



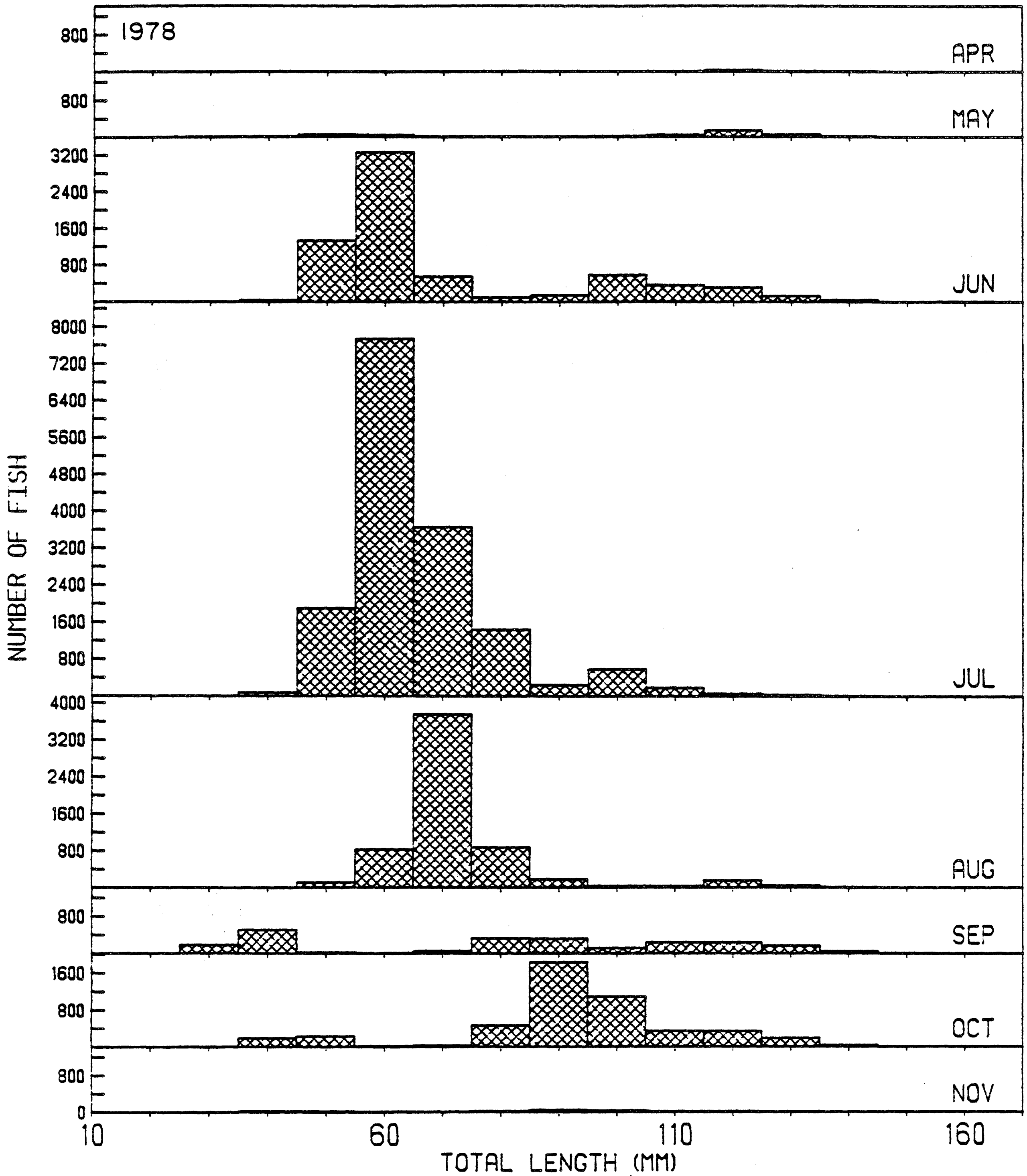
Appendix 29. Length-frequency histograms of spottail shiners impinged during 1977 at the Cook Plant, southeastern Lake Michigan.



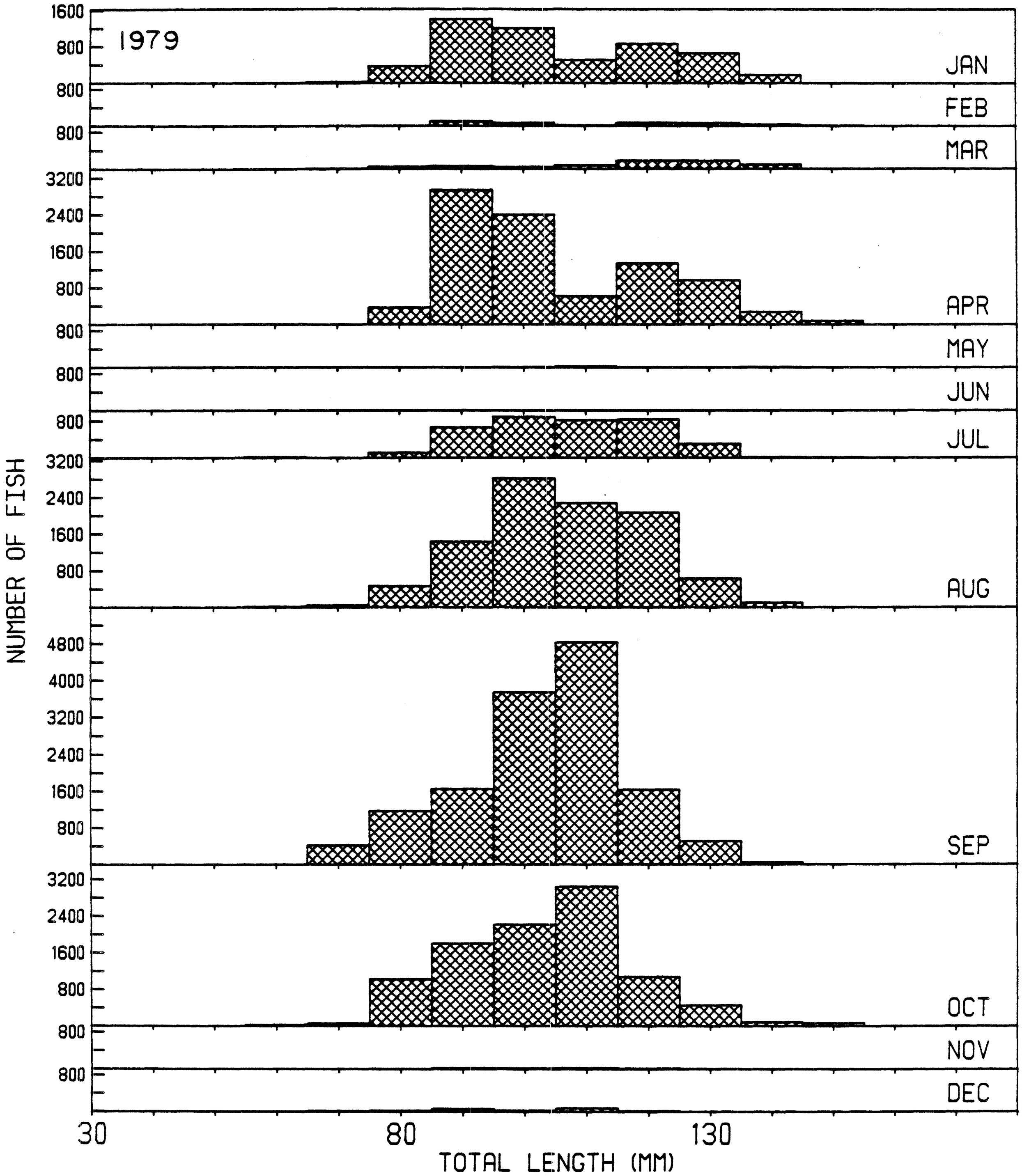
Appendix 30. Length-frequency histograms of spottail shiners caught during 1977 field sampling at the Cook Plant, southeastern Lake Michigan.



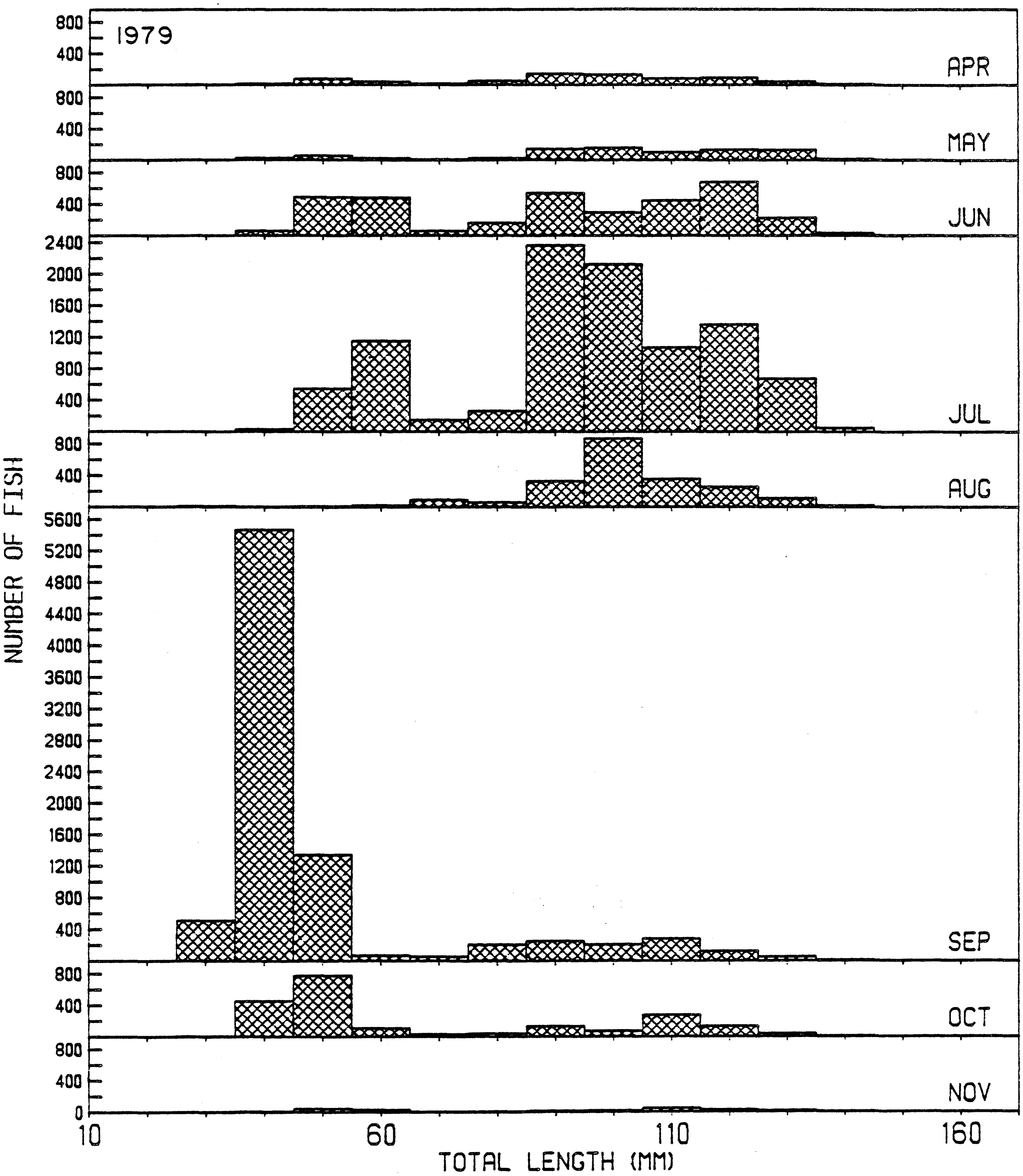
Appendix 31. Length-frequency histograms of spottail shiners impinged during 1978 at the Cook Plant, southeastern Lake Michigan.



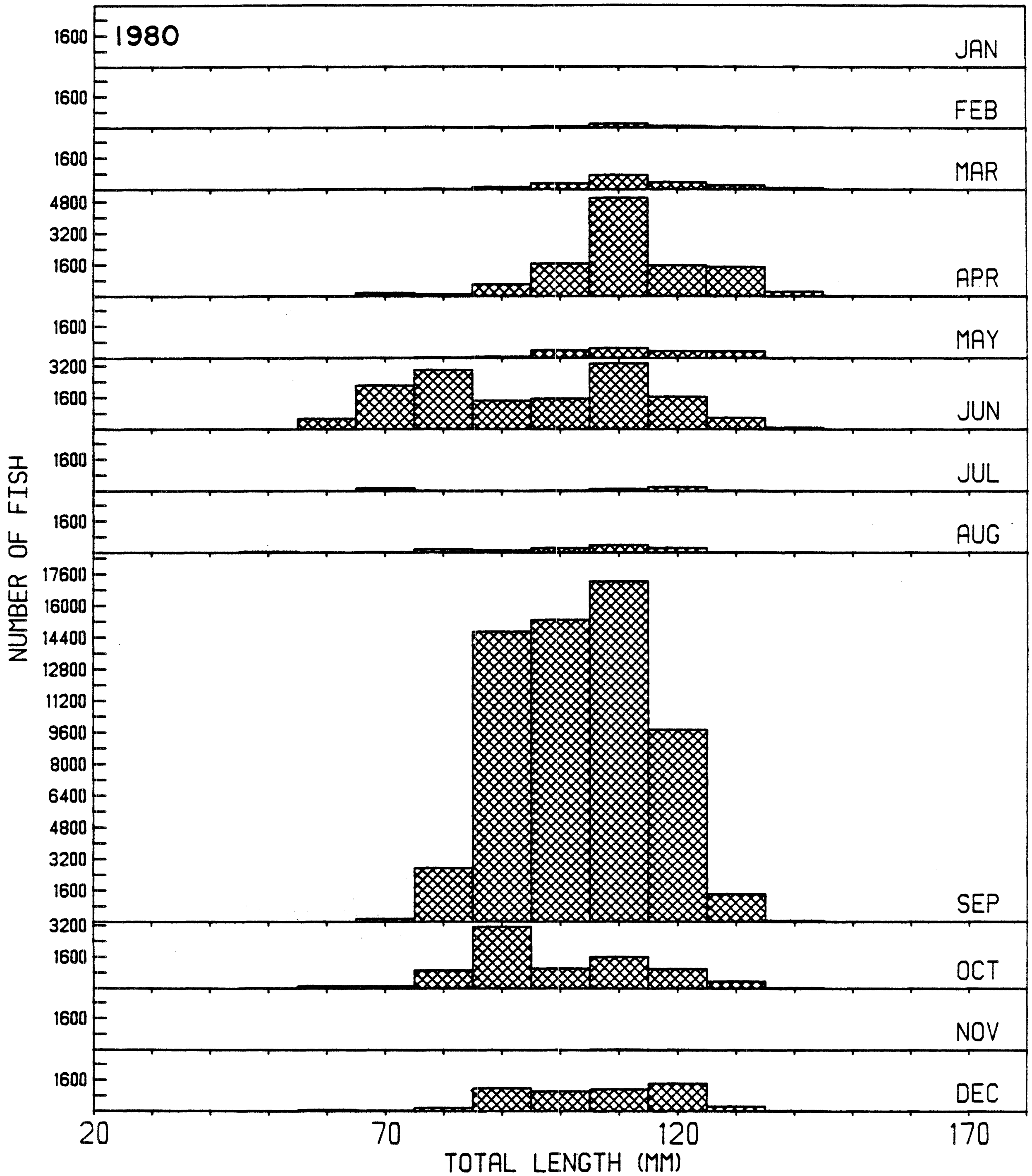
Appendix 32. Length-frequency histograms of spottail shiners caught during 1978 field sampling at the Cook Plant, southeastern Lake Michigan.



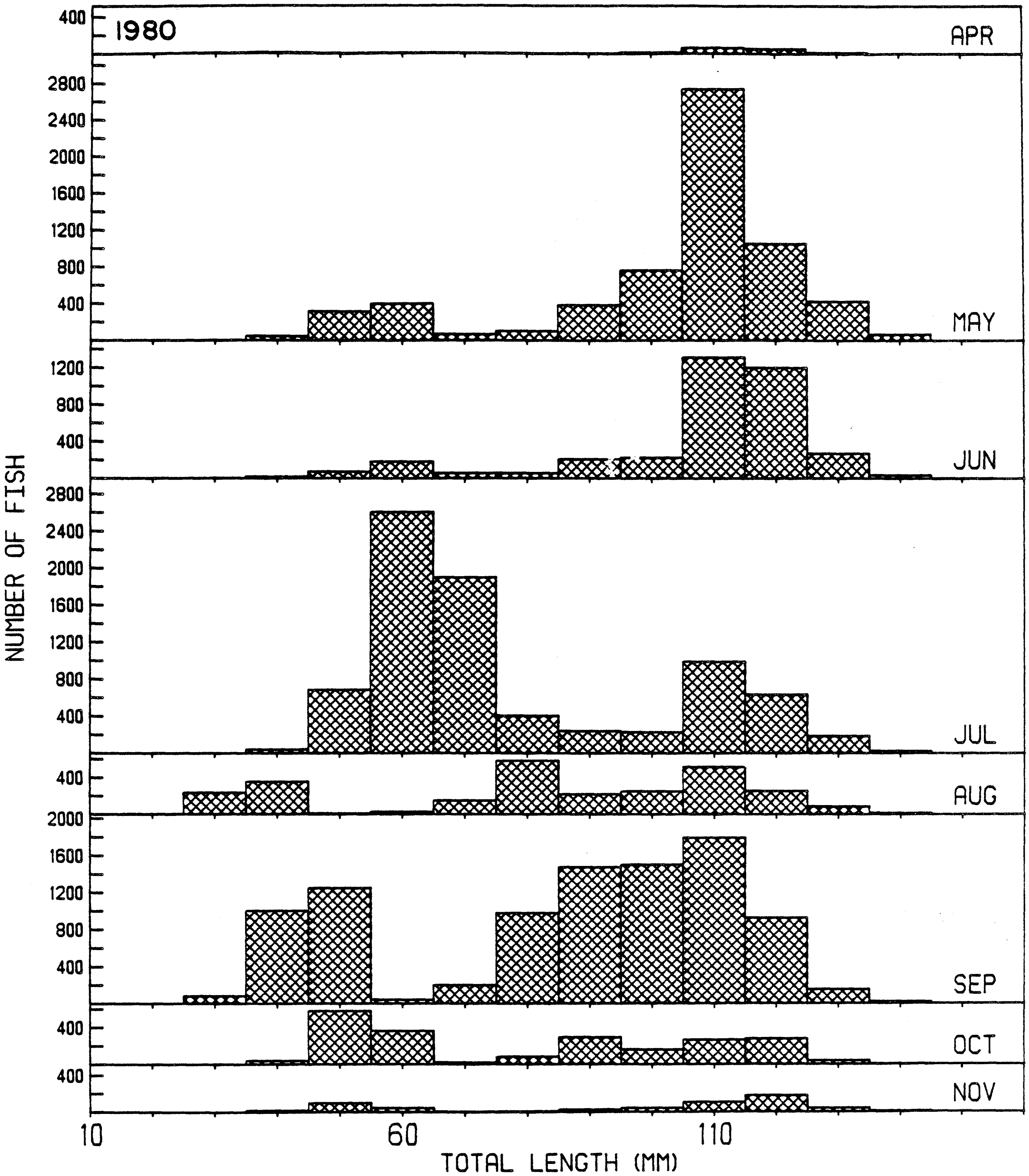
Appendix 33. Length-frequency histograms of spottail shiners impinged during 1979 at the Cook Plant, southeastern Lake Michigan.



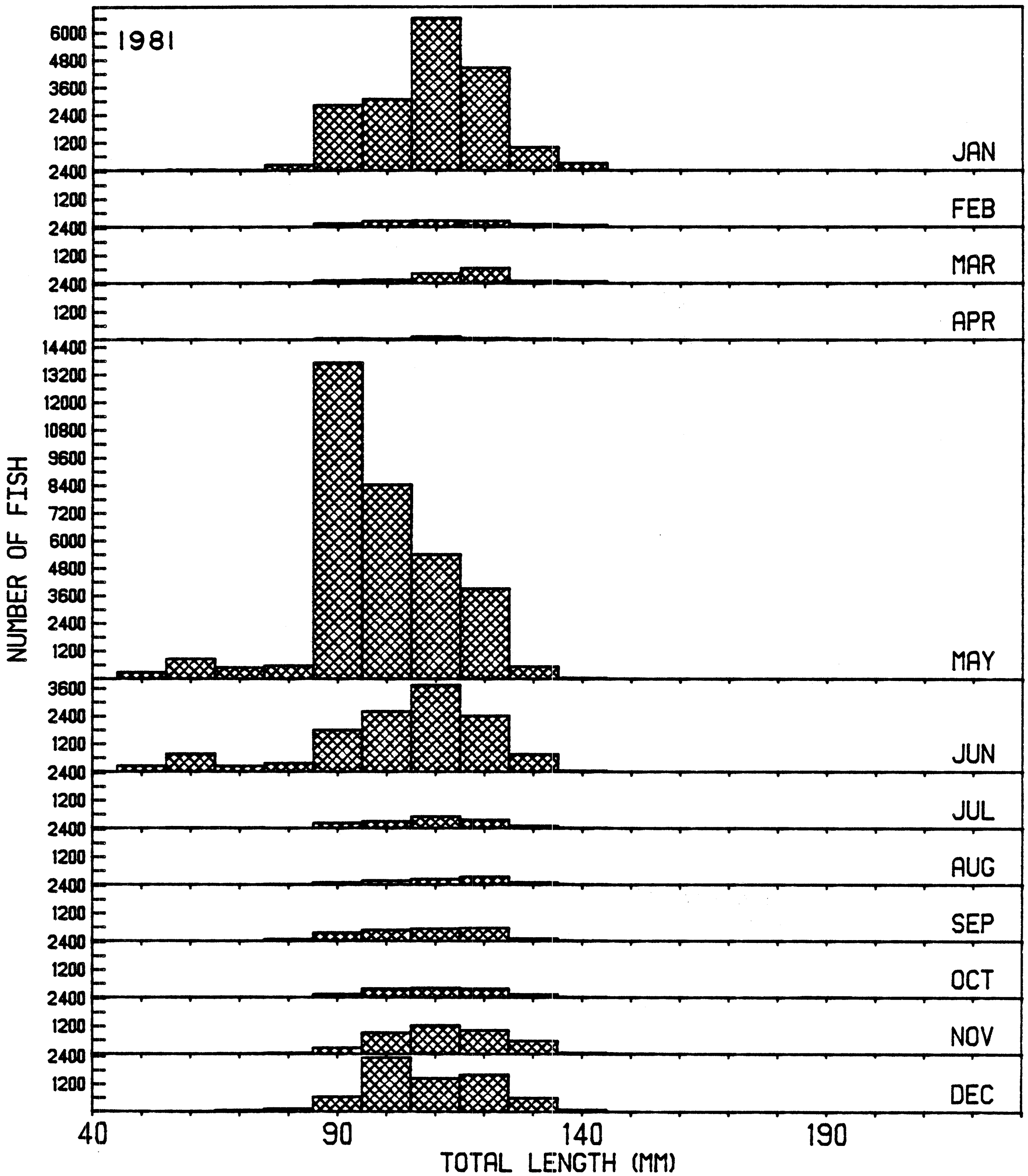
Appendix 34. Length-frequency histograms of spottail shiners caught during 1979 field sampling at the Cook Plant, southeastern Lake Michigan.



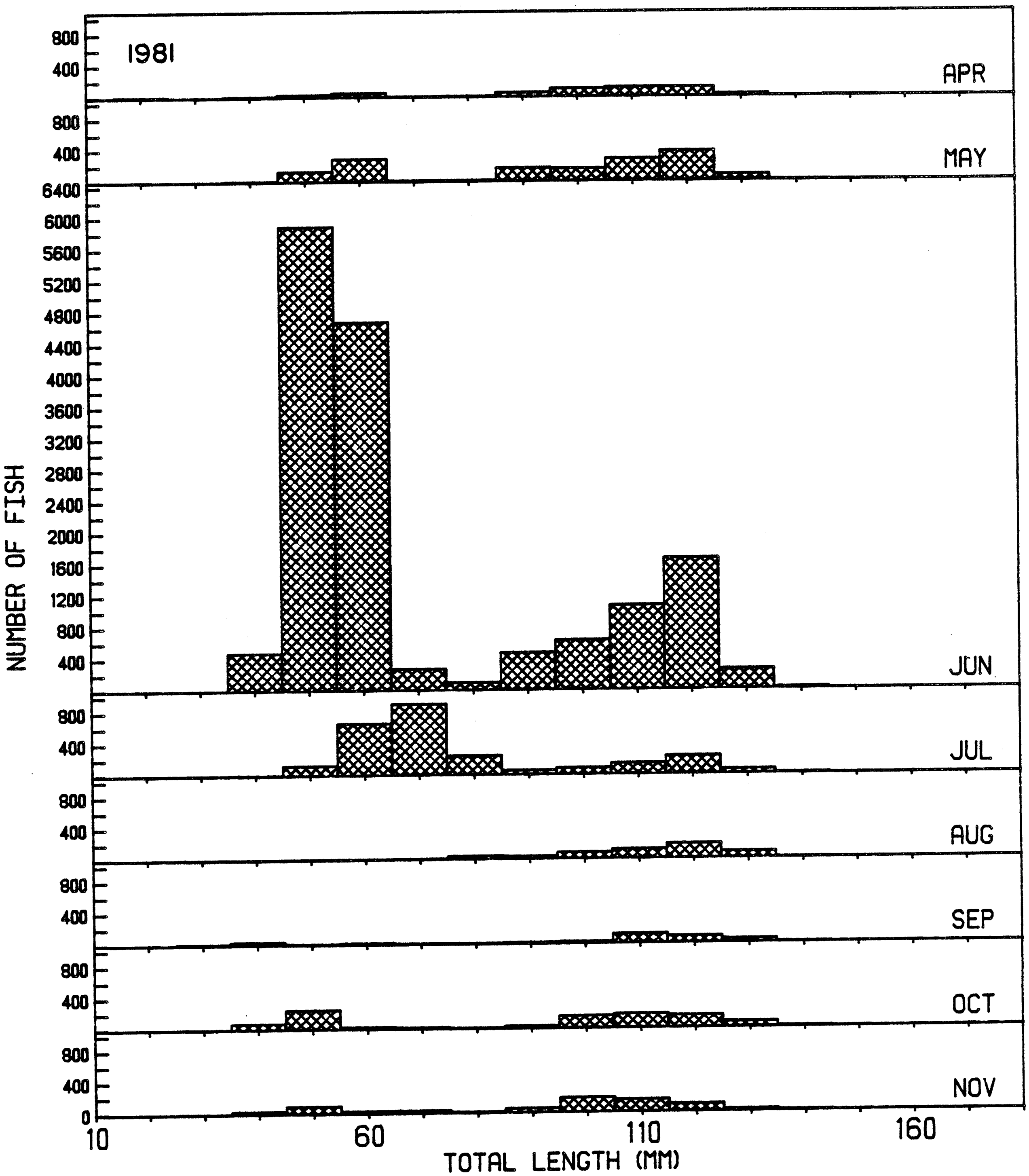
Appendix 35. Length-frequency histograms of spottail shiners impinged during 1980 at the Cook Plant, southeastern Lake Michigan.



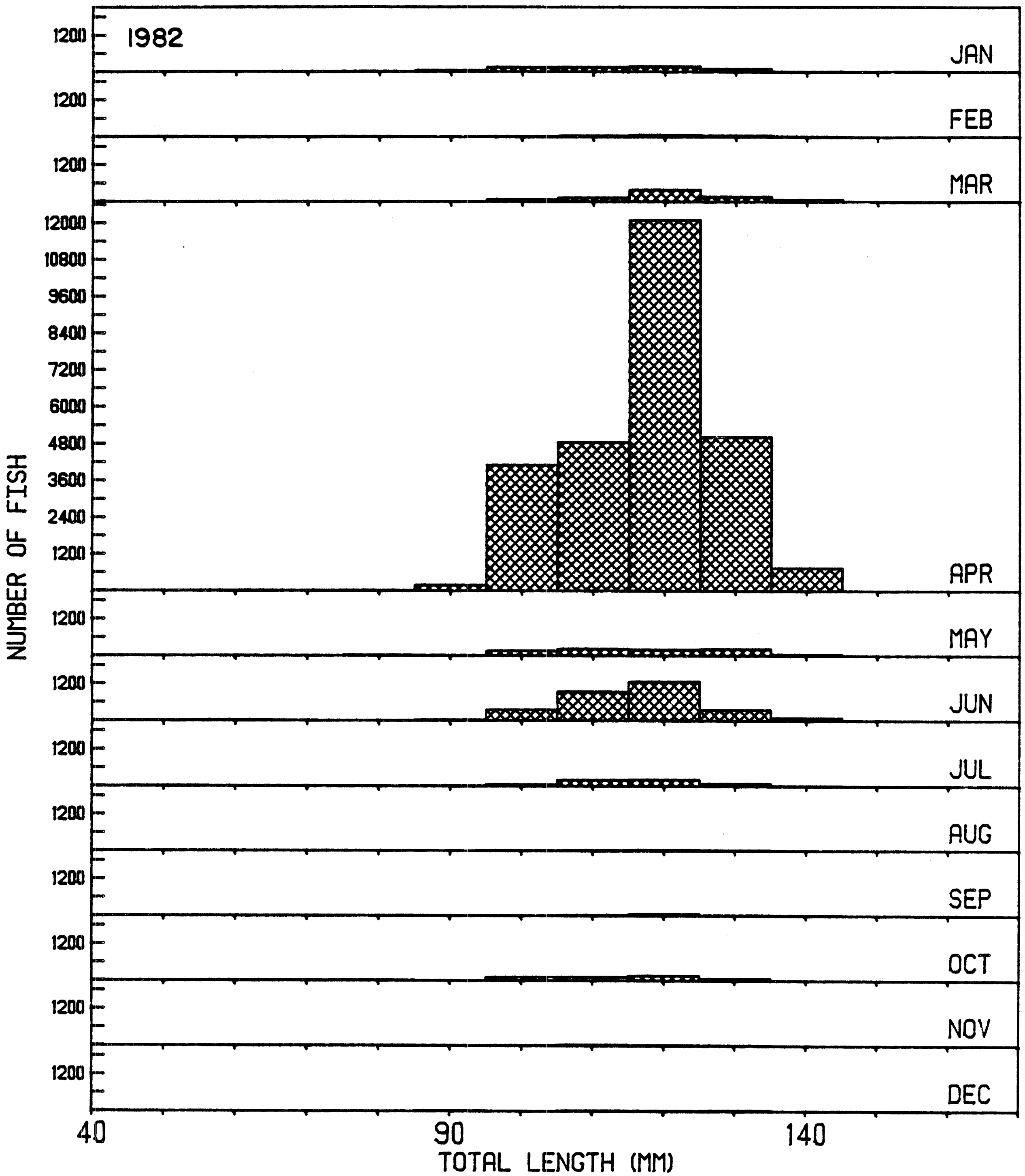
Appendix 36. Length-frequency histograms of spottail shiners caught during 1980 field sampling at the Cook Plant, southeastern Lake Michigan.



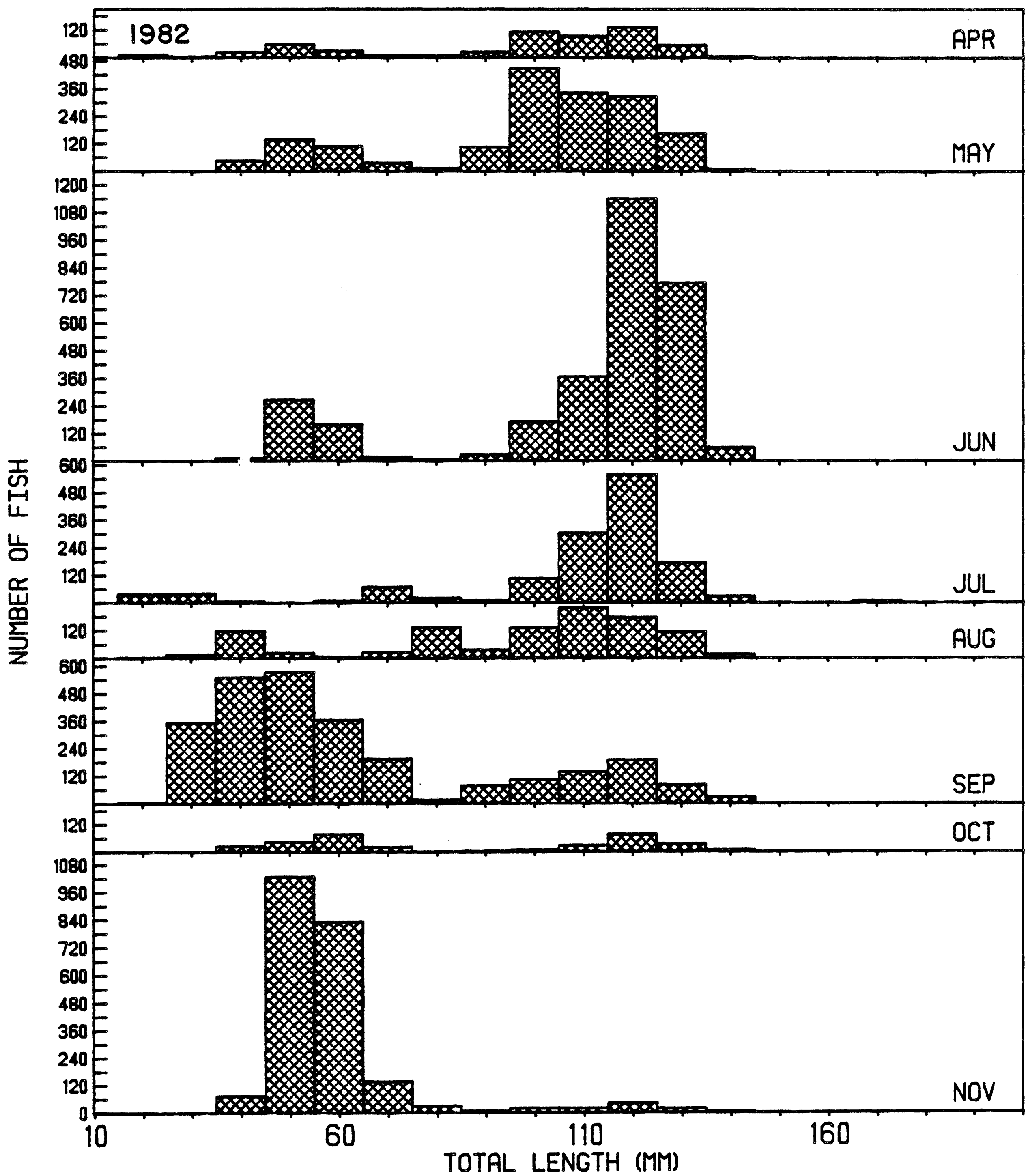
Appendix 37. Length-frequency histograms of spottail shiners impinged during 1981 at the Cook Plant, southeastern Lake Michigan.



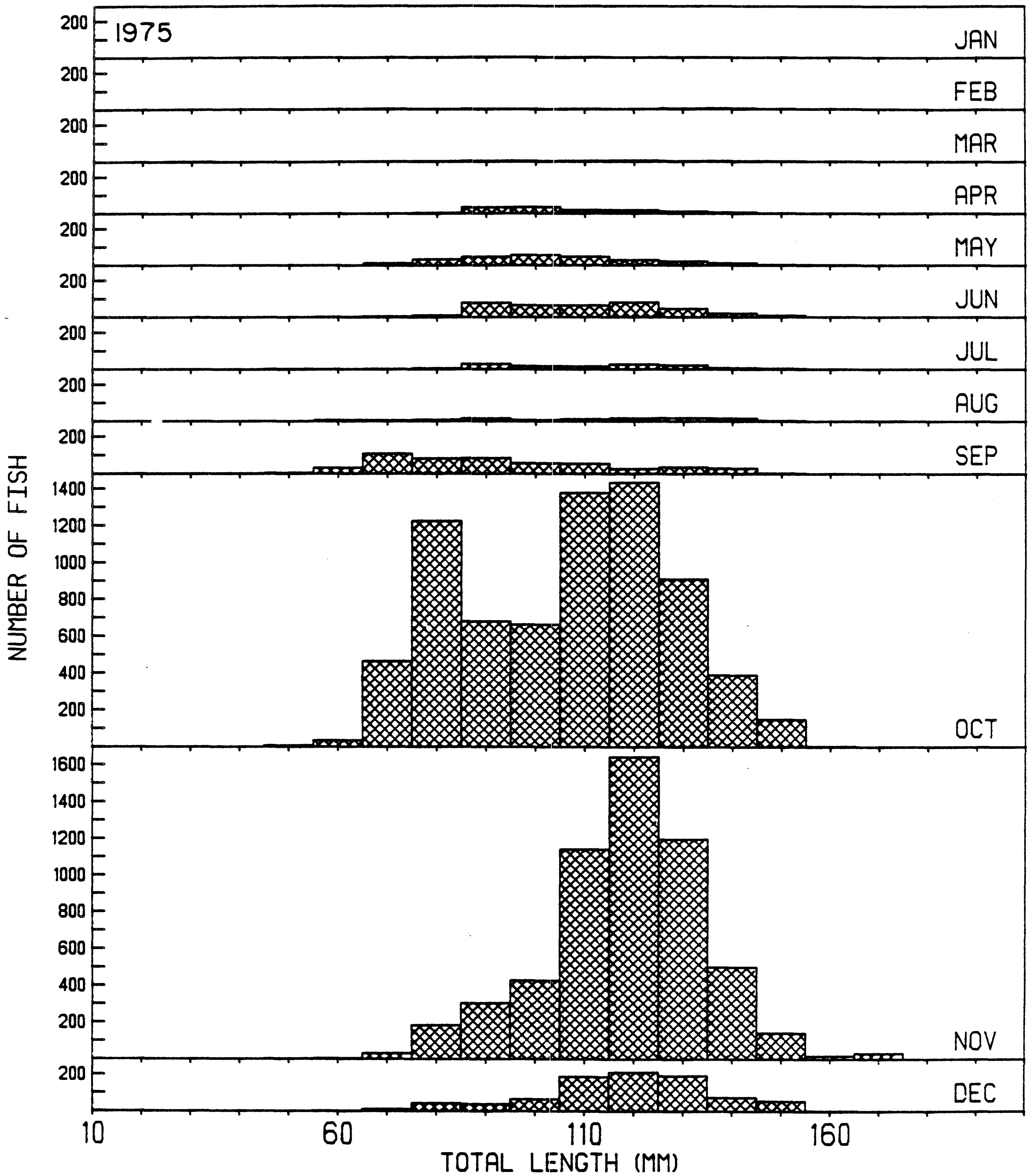
Appendix 38. Length-frequency histograms of spottail shiners caught during 1981 field sampling at the Cook Plant, southeastern Lake Michigan.



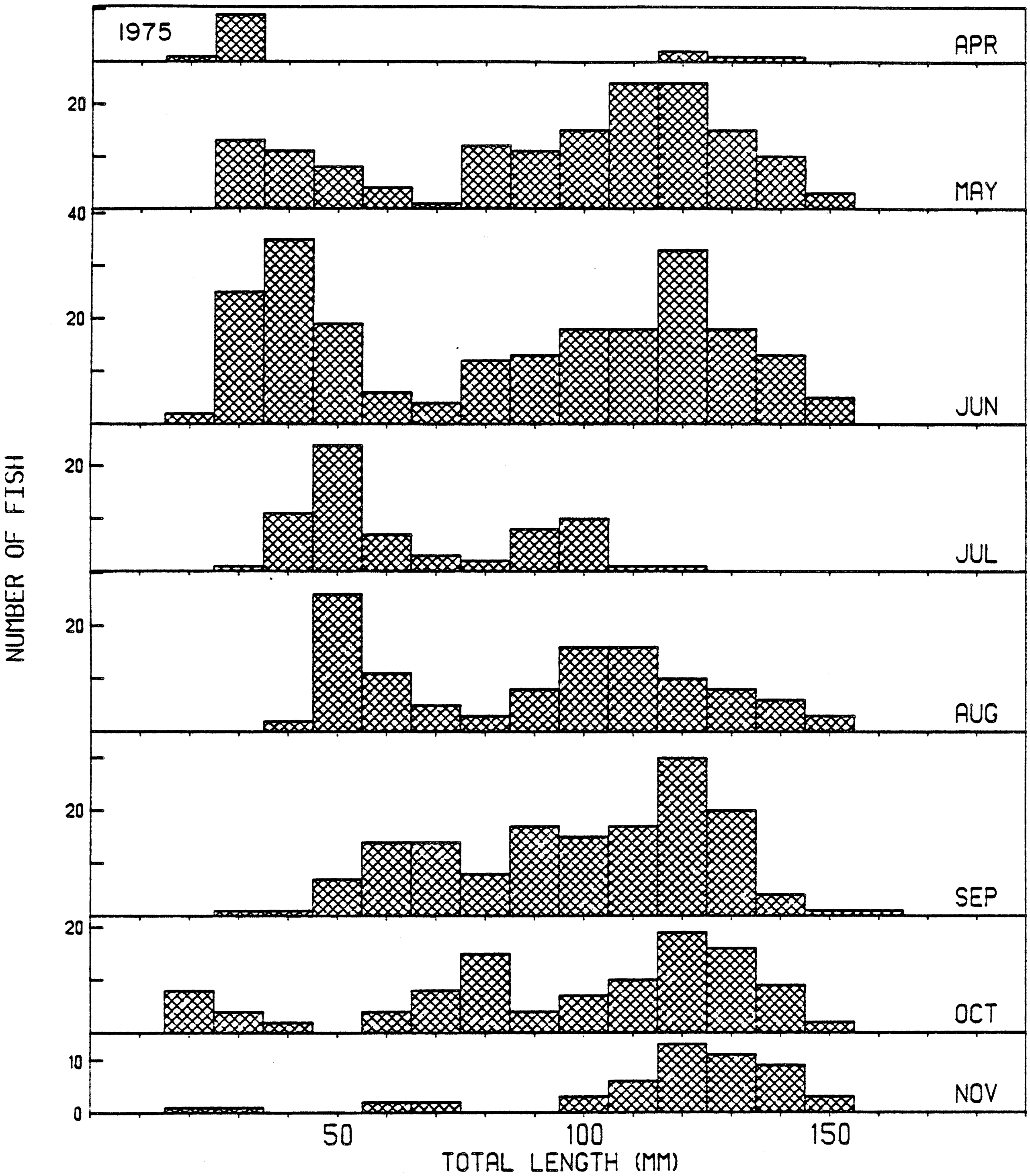
Appendix 39. Length-frequency histograms of spottail shiners impinged during 1982 at the Cook Plant, southeastern Lake Michigan.



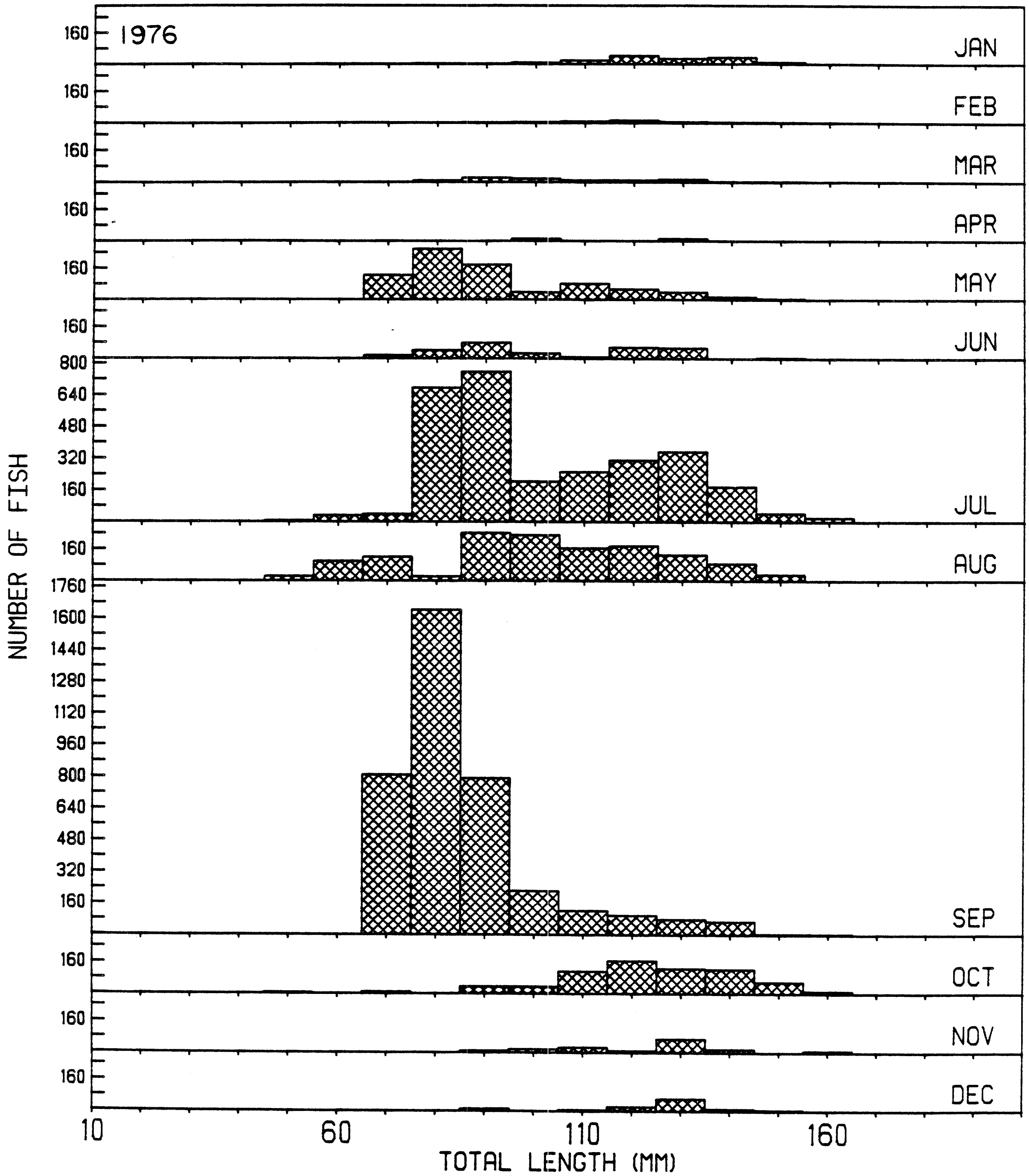
Appendix 40. Length-frequency histograms of spottail shiners caught during 1982 field sampling at the Cook Plant, southeastern Lake Michigan.



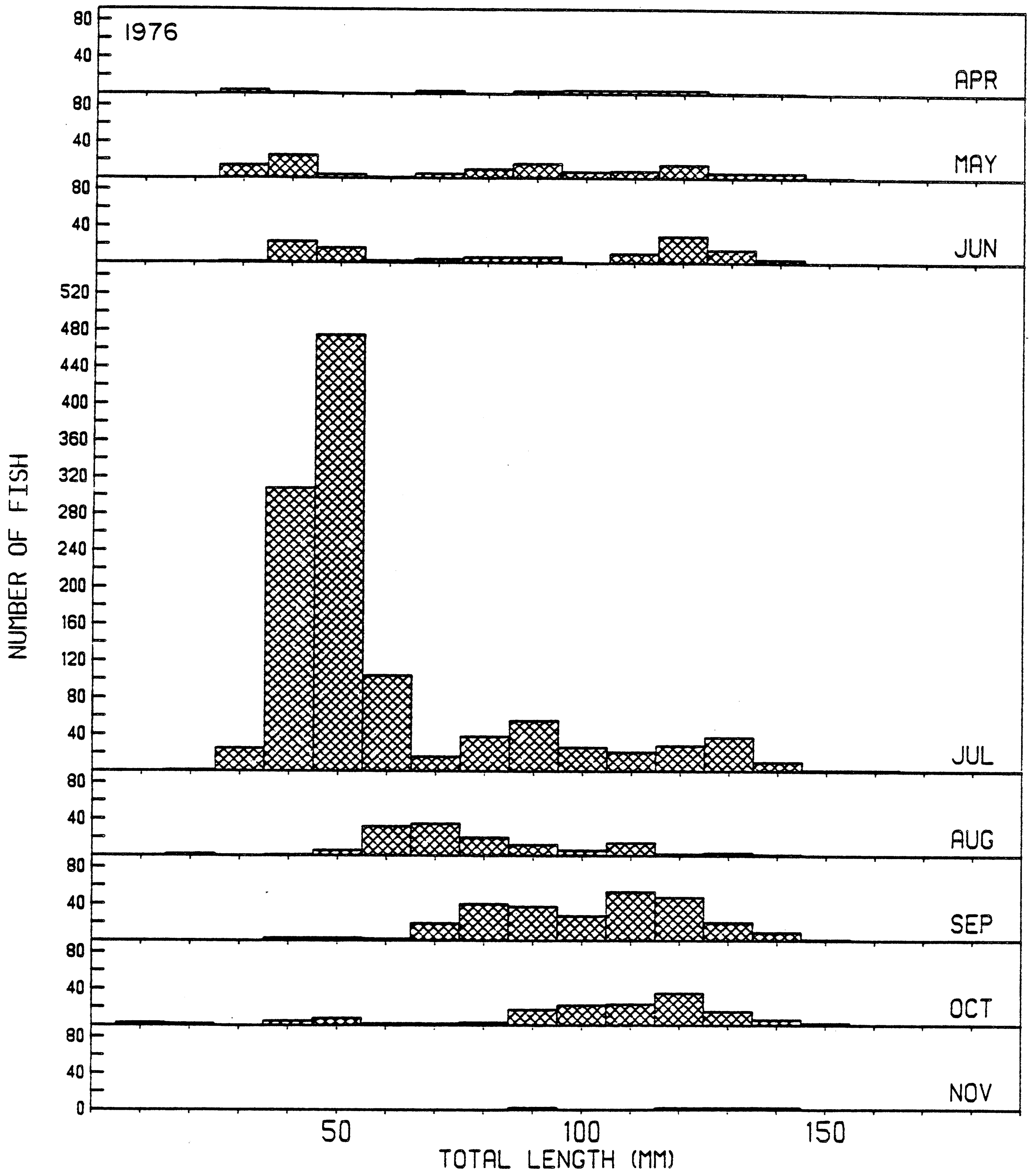
Appendix 41. Length-frequency histograms of trout-perch impinged during 1975 at the Cook Plant, southeastern Lake Michigan.



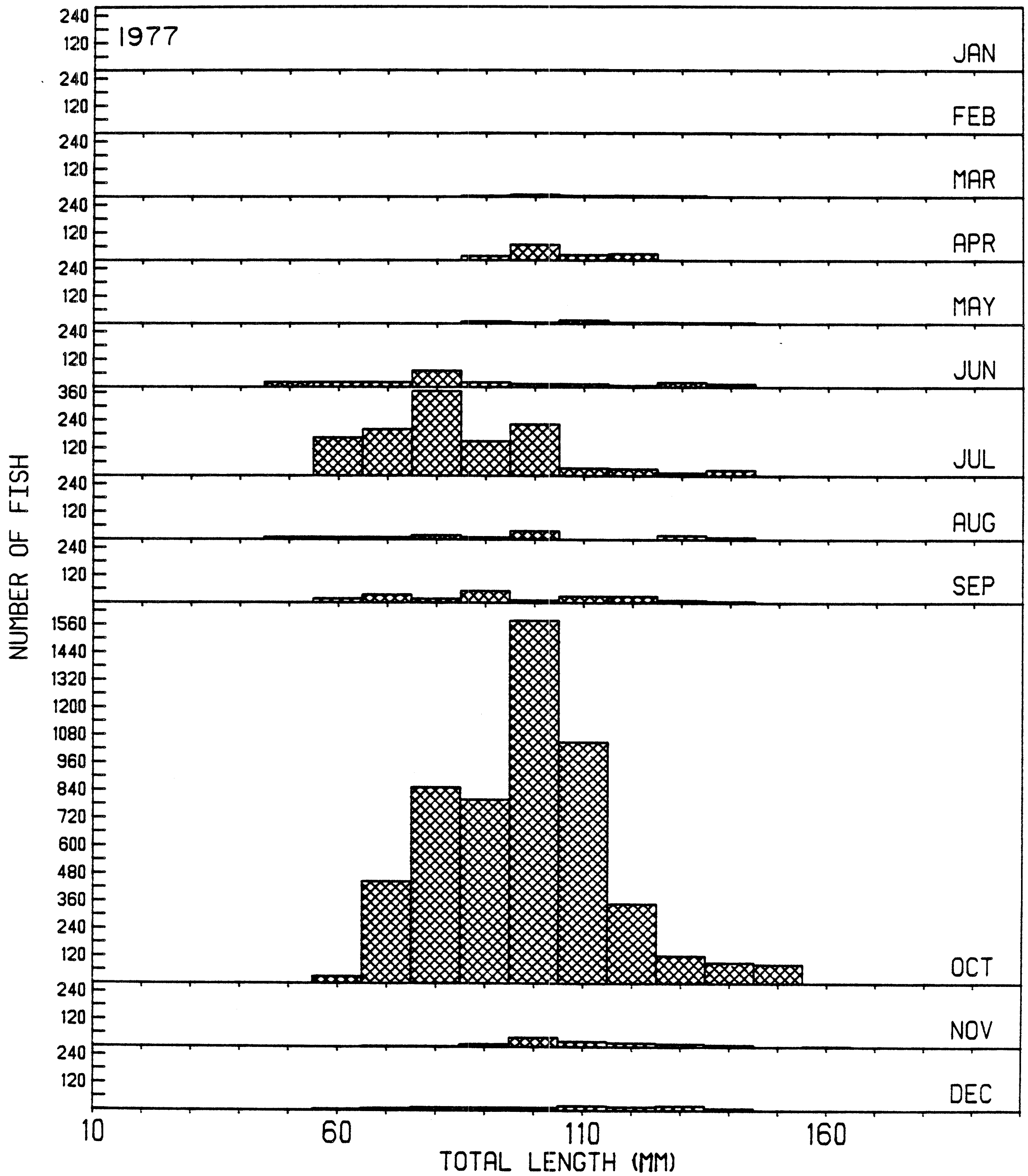
Appendix 42. Length-frequency histograms of trout-perch caught during 1975 field sampling at the Cook Plant, southeastern Lake Michigan.



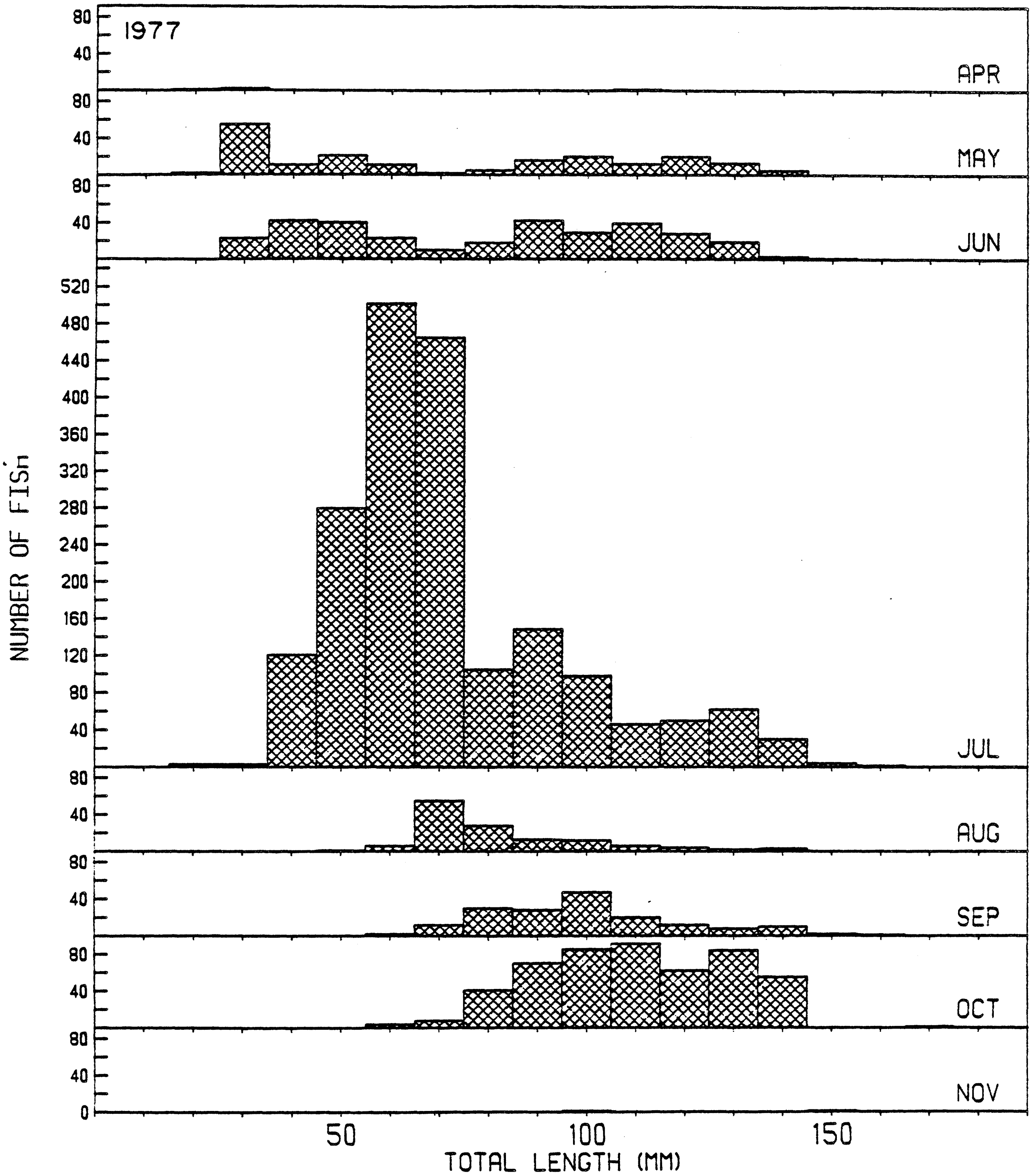
Appendix 43. Length-frequency histograms of trout-perch impinged during 1976 at the Cook Plant, southeastern Lake Michigan.



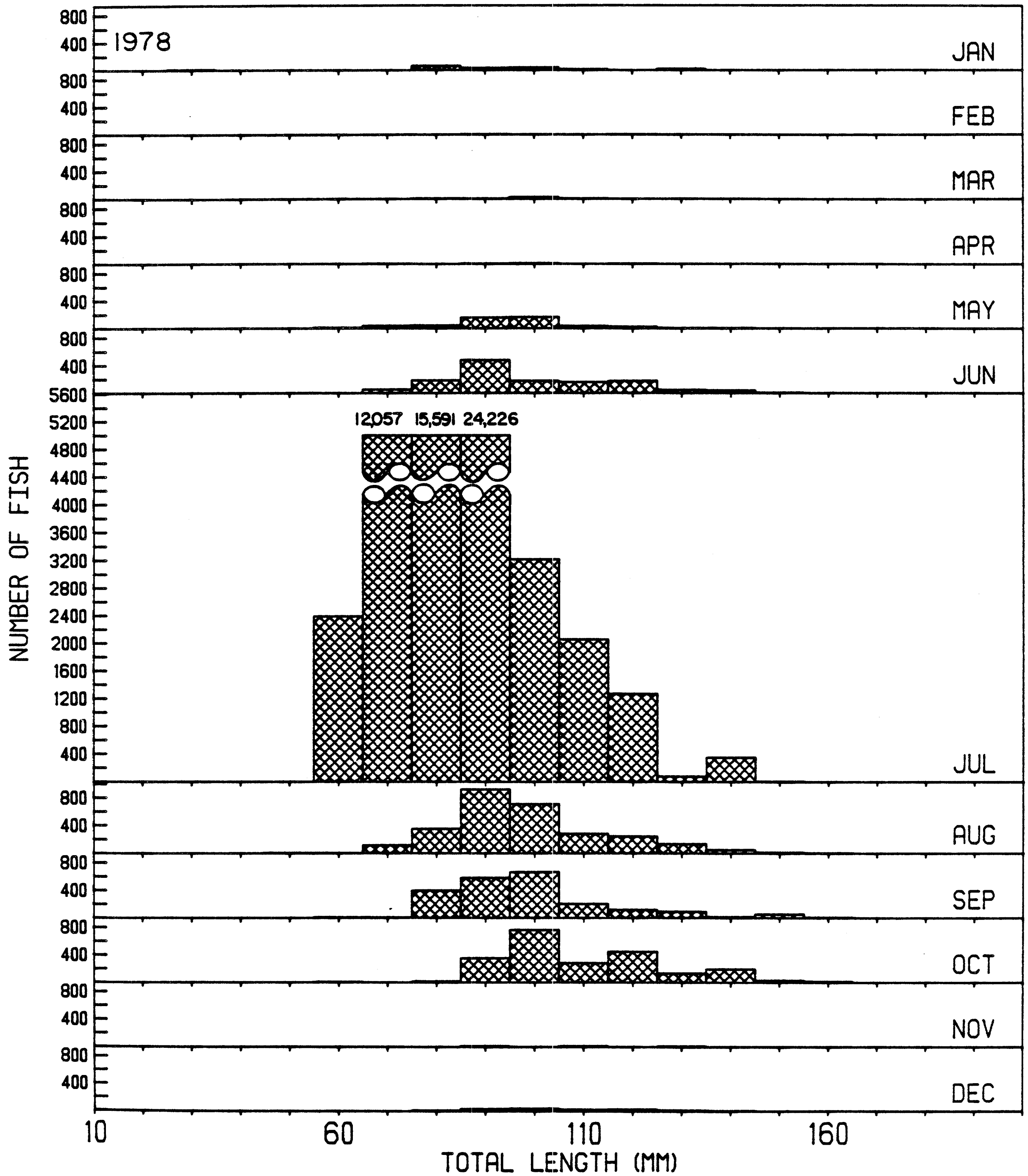
Appendix 44. Length-frequency histograms of trout-perch caught during 1976 field sampling at the Cook Plant, southeastern Lake Michigan.



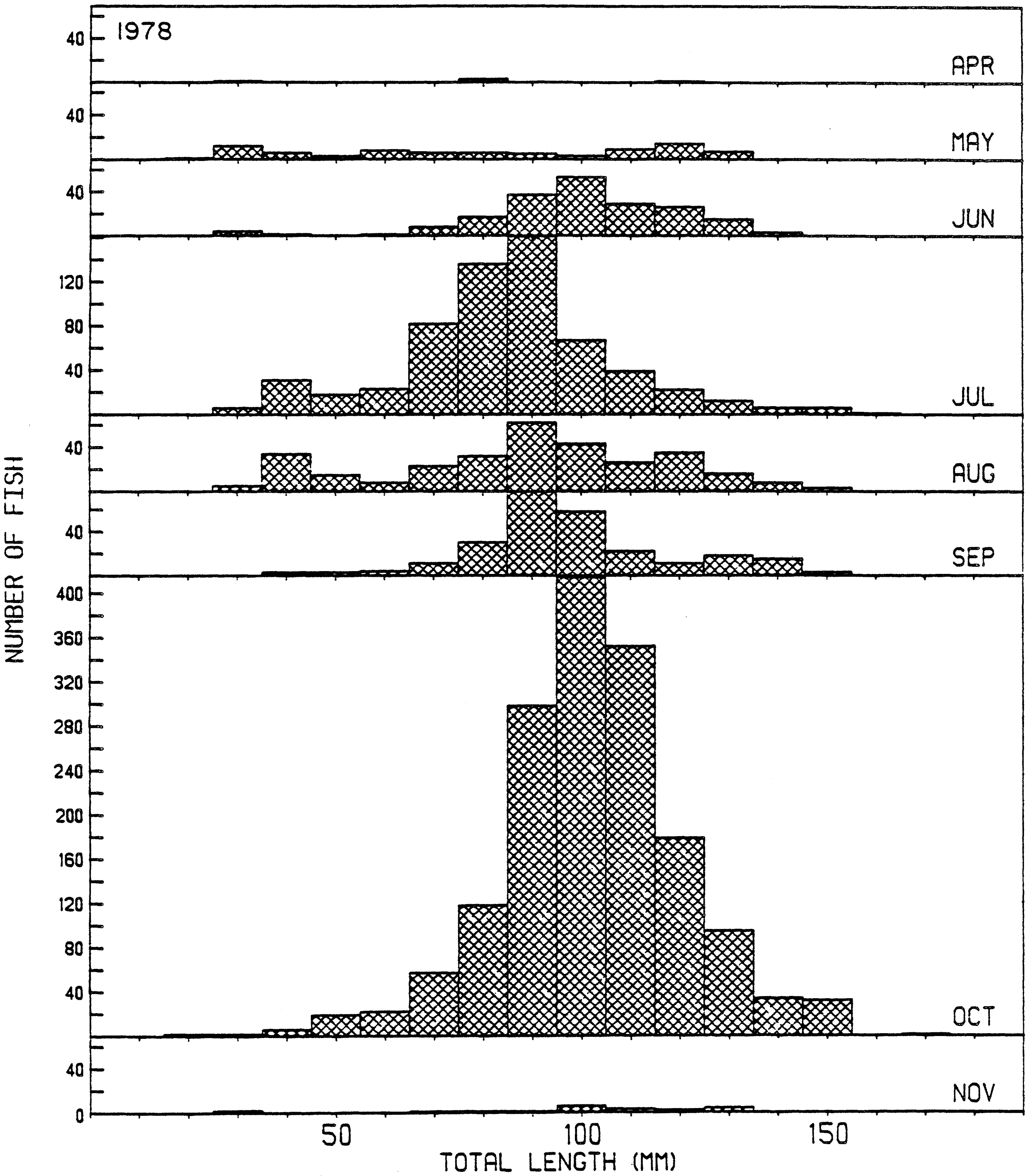
Appendix 45. Length-frequency histograms of trout-perch impinged during 1977 at the Cook Plant, southeastern Lake Michigan.



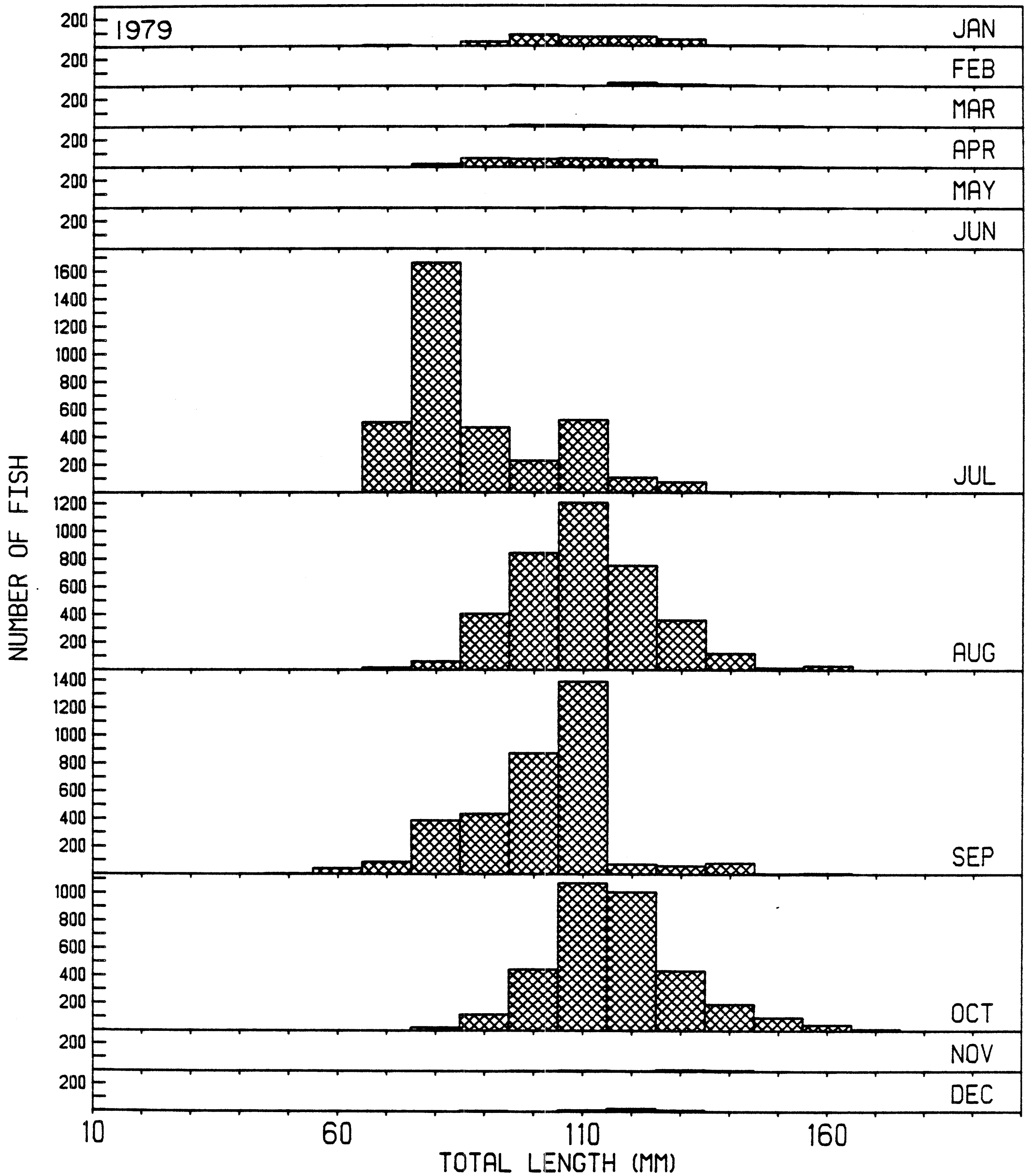
Appendix 46. Length-frequency histograms of trout-perch caught during 1977 field sampling at the Cook Plant, southeastern Lake Michigan.



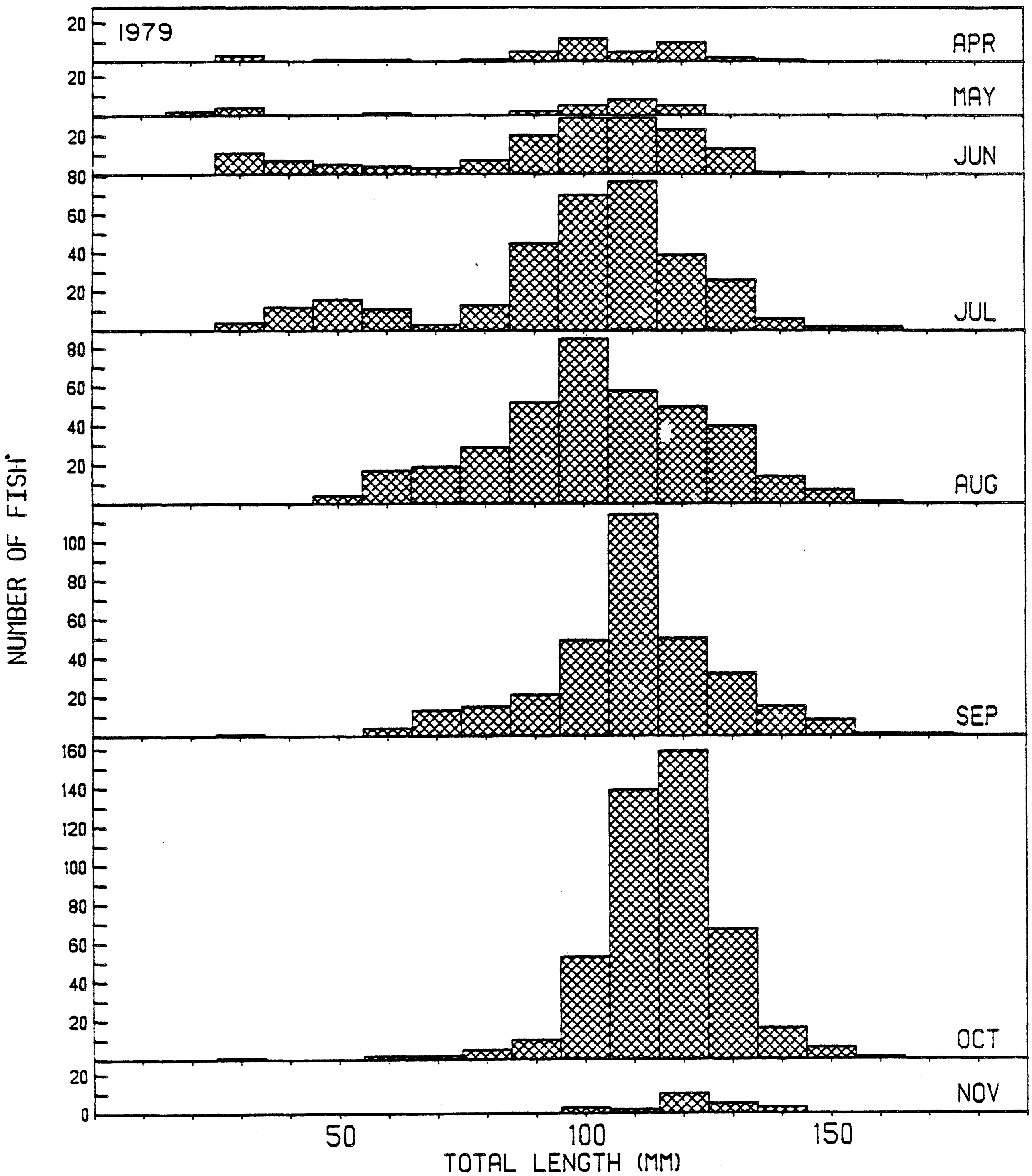
Appendix 47. Length-frequency histograms of trout-perch impinged during 1978 at the Cook Plant, southeastern Lake Michigan.



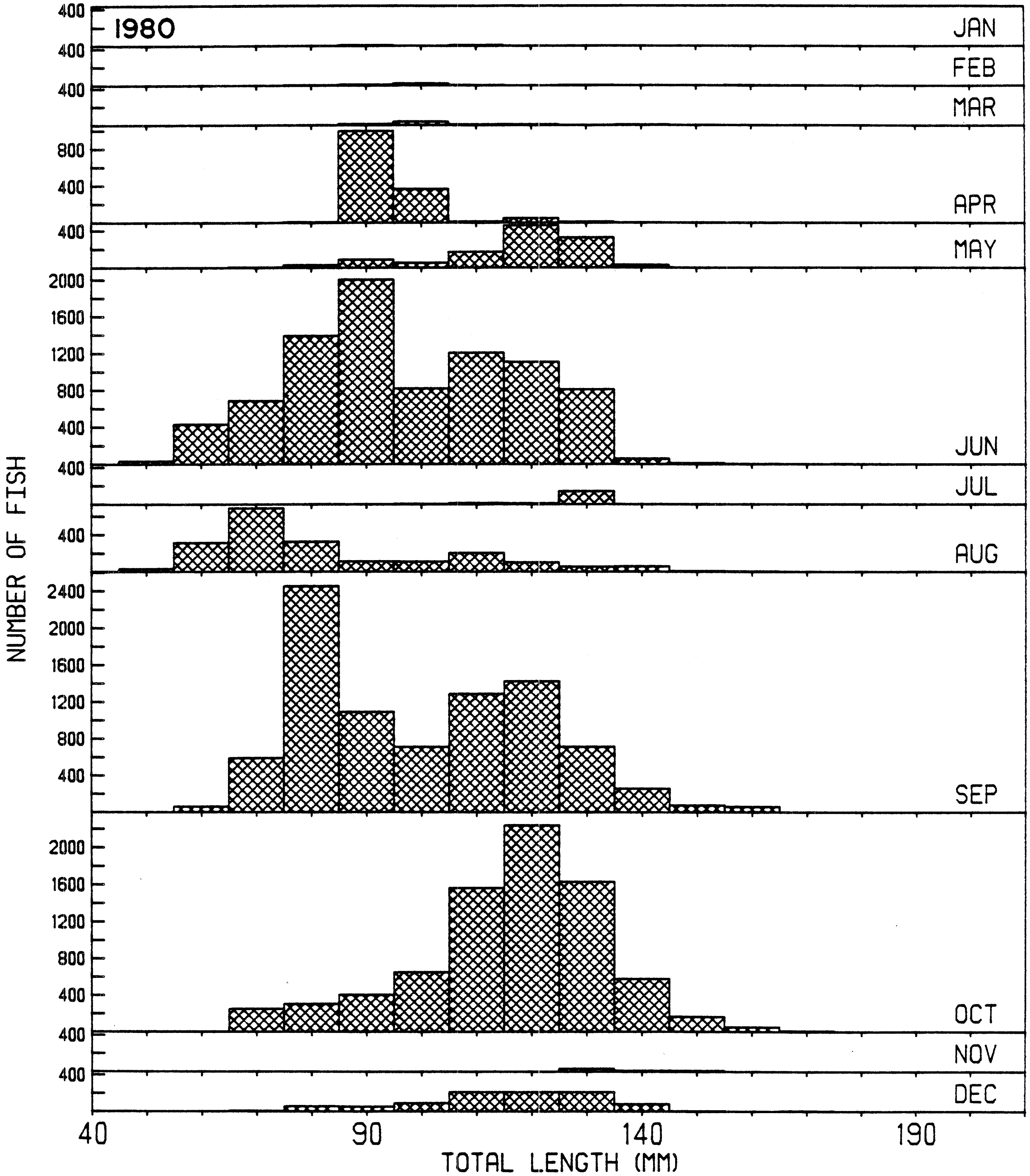
Appendix 48. Length-frequency histograms of trout-perch caught during 1978 field sampling at the Cook Plant, southeastern Lake Michigan.



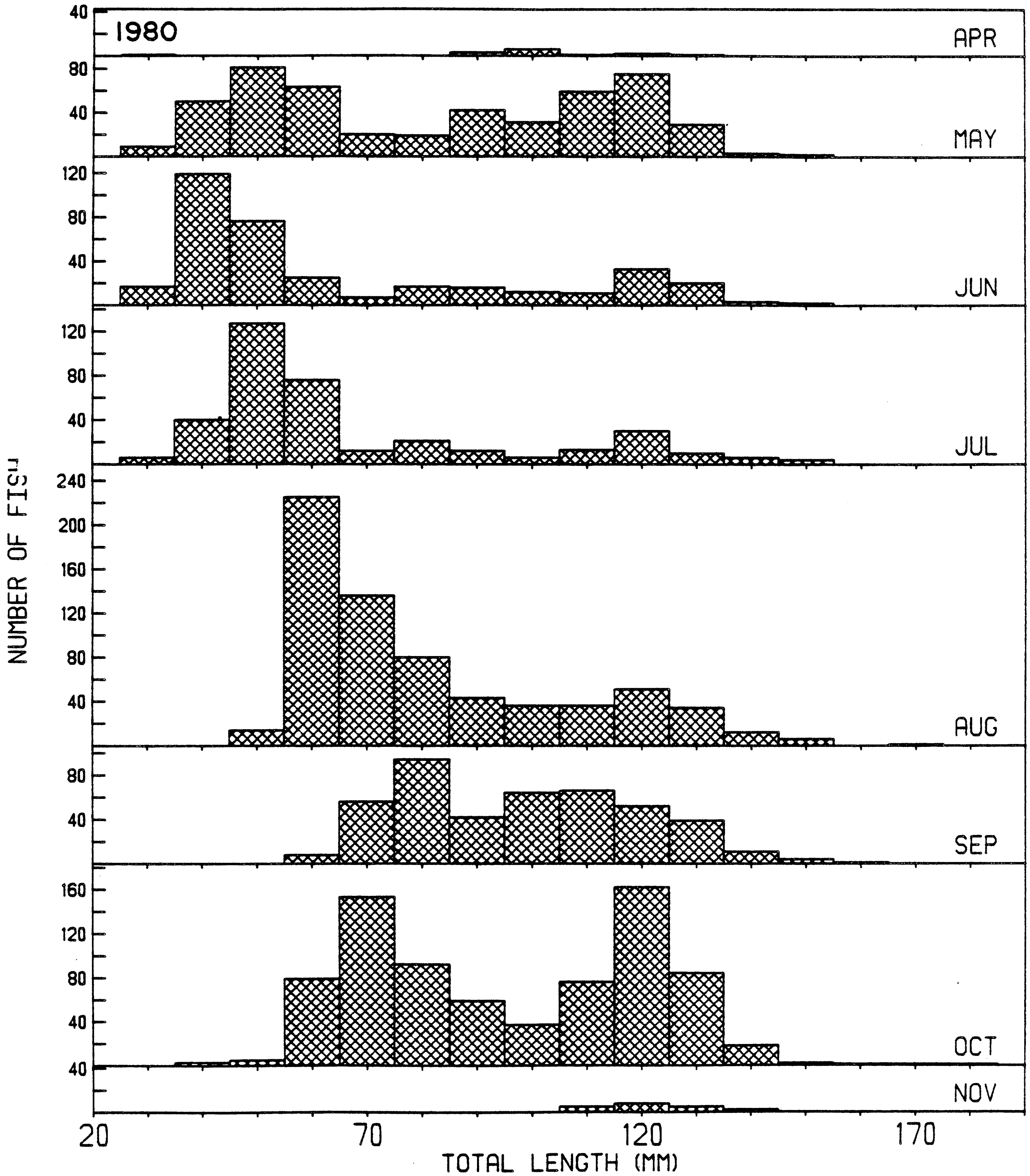
Appendix 49. Length-frequency histograms of trout-perch impinged during 1979 at the Cook Plant, southeastern Lake Michigan.



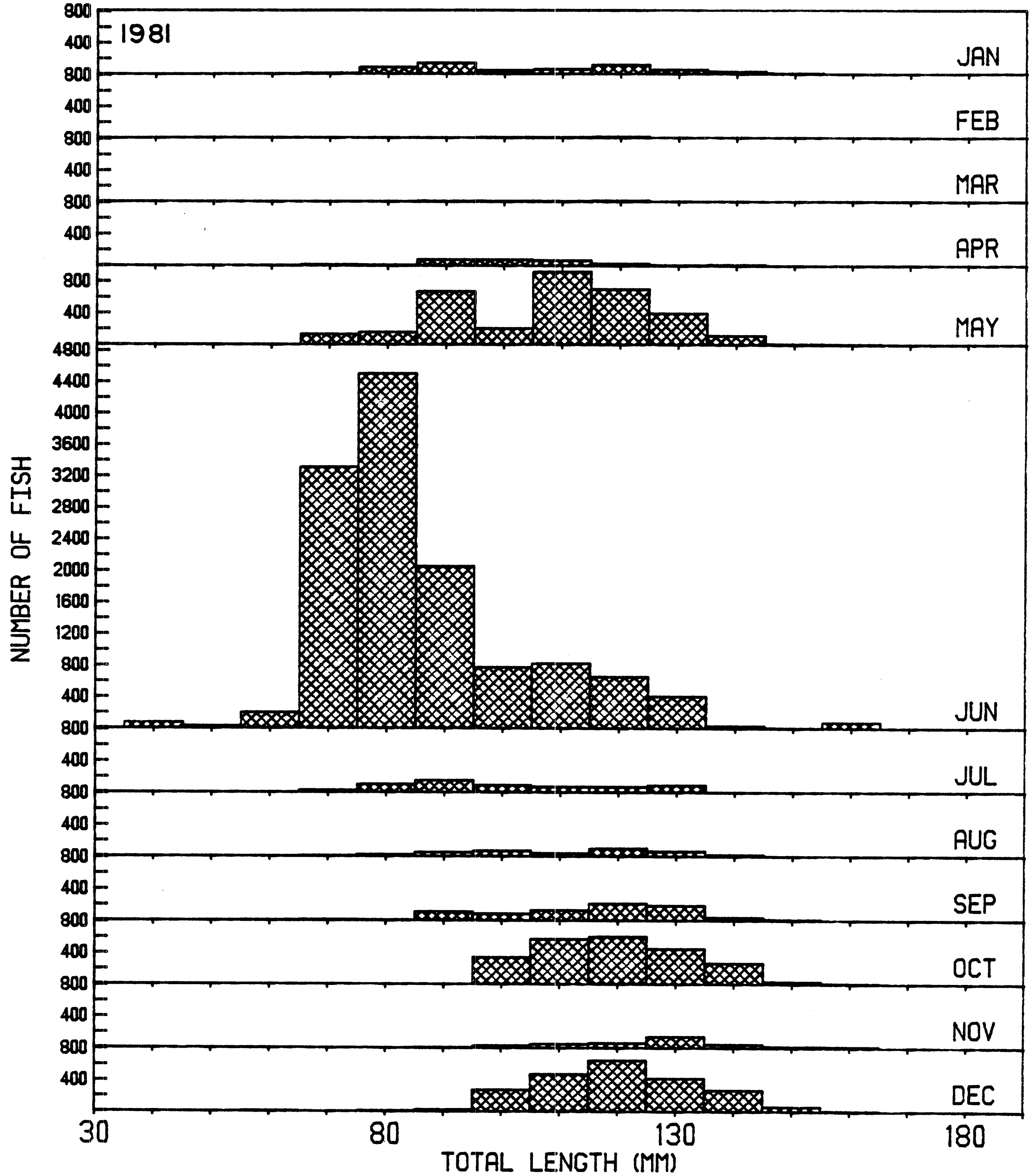
Appendix 50. Length-frequency histograms of trout-perch caught during 1979 field sampling at the Cook Plant, southeastern Lake Michigan.



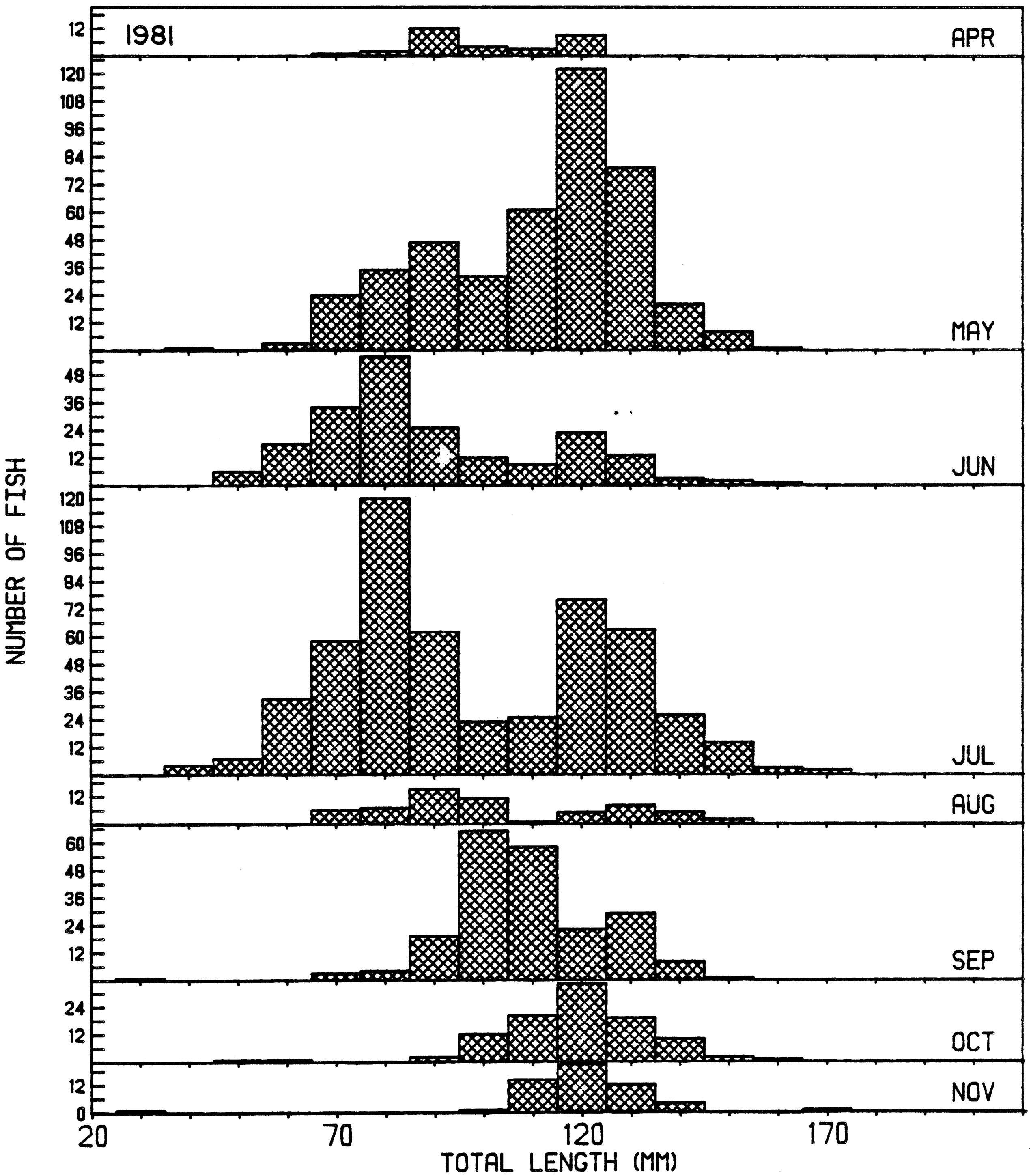
Appendix 51. Length-frequency histograms of trout-perch impinged during 1980 at the Cook Plant, southeastern Lake Michigan.



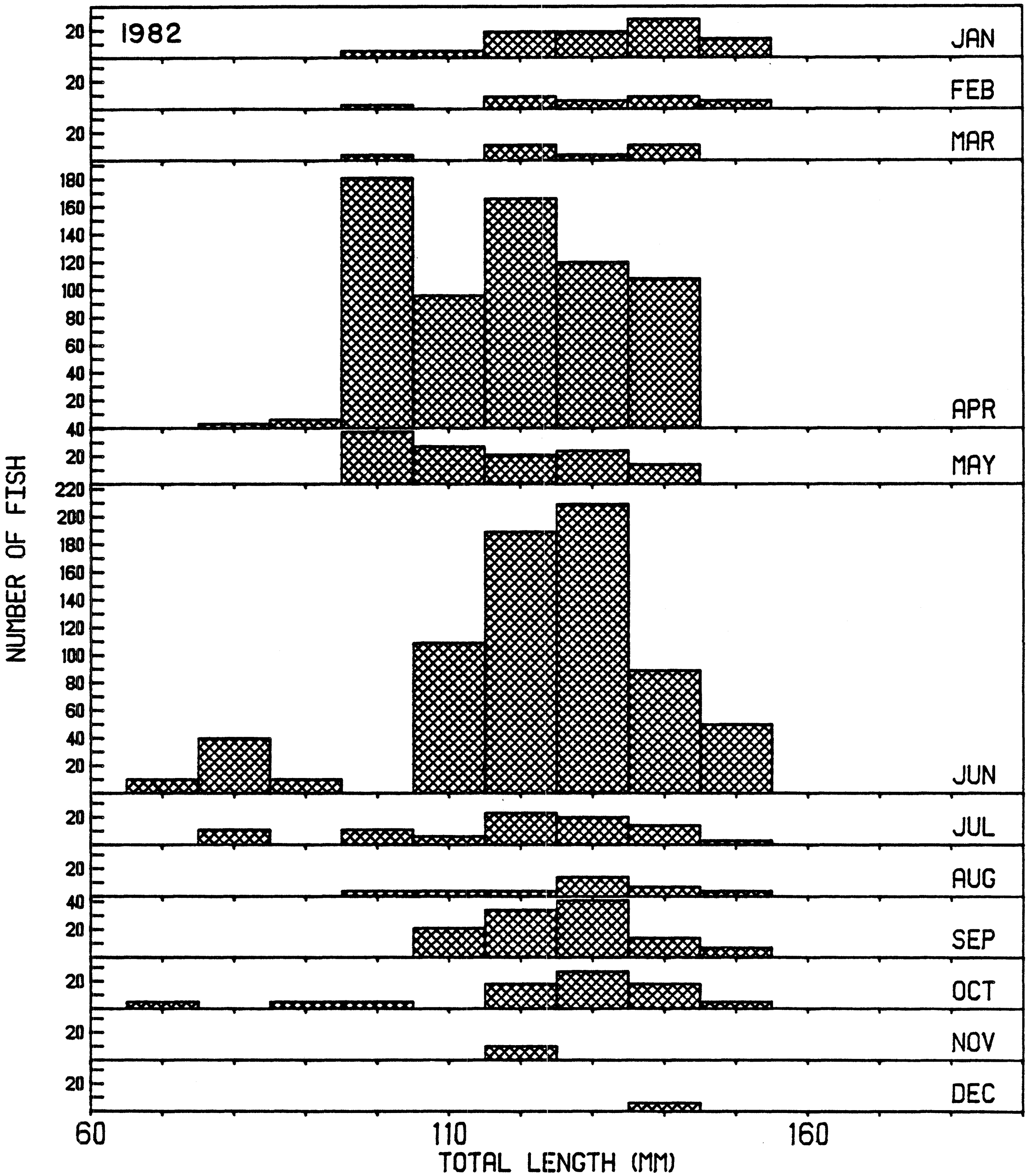
Appendix 52. Length-frequency histograms of trout-perch caught during 1980 field sampling at the Cook Plant, southeastern Lake Michigan.



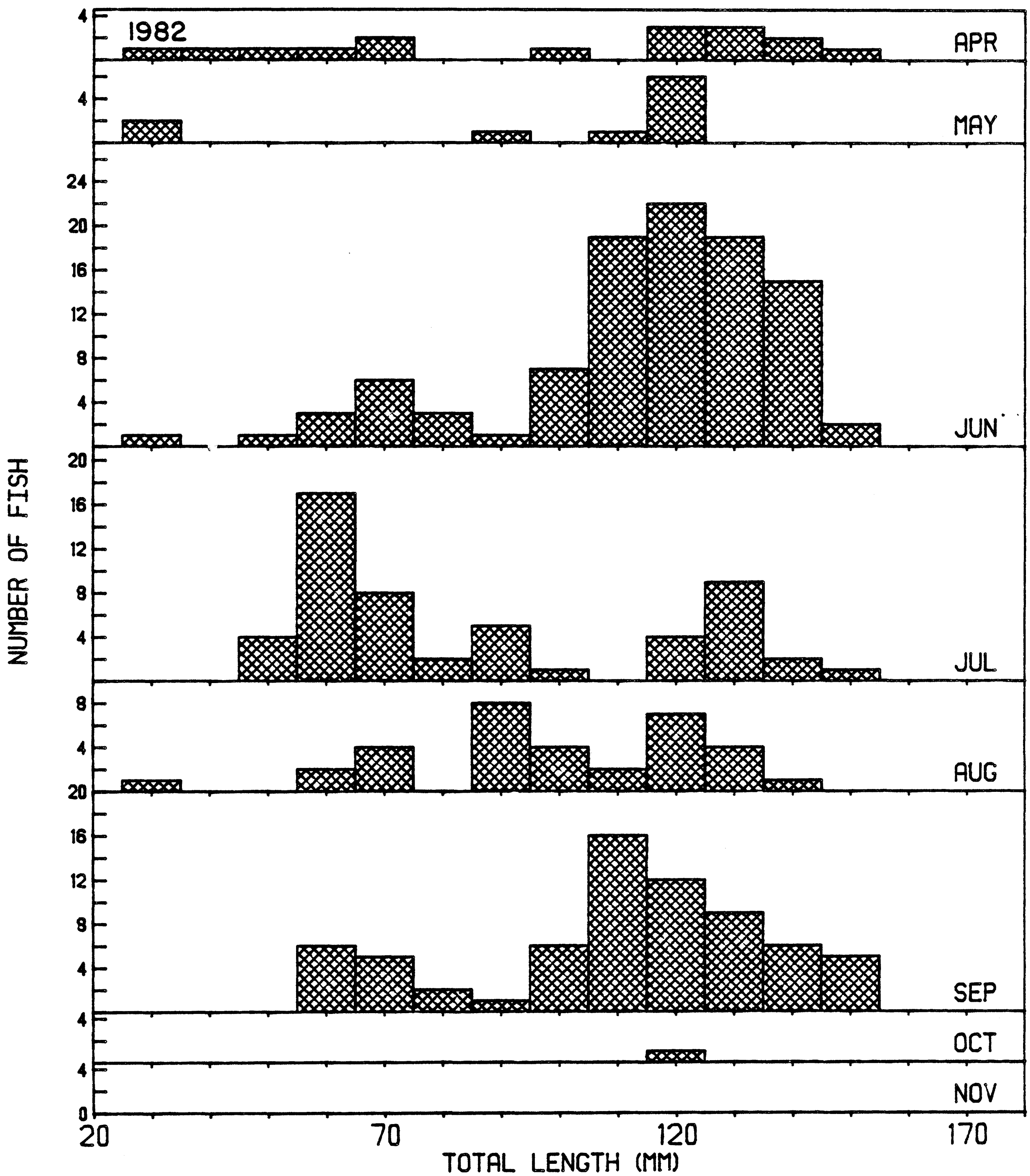
Appendix 53. Length-frequency histograms of trout-perch impinged during 1981 at the Cook Plant, southeastern Lake Michigan.



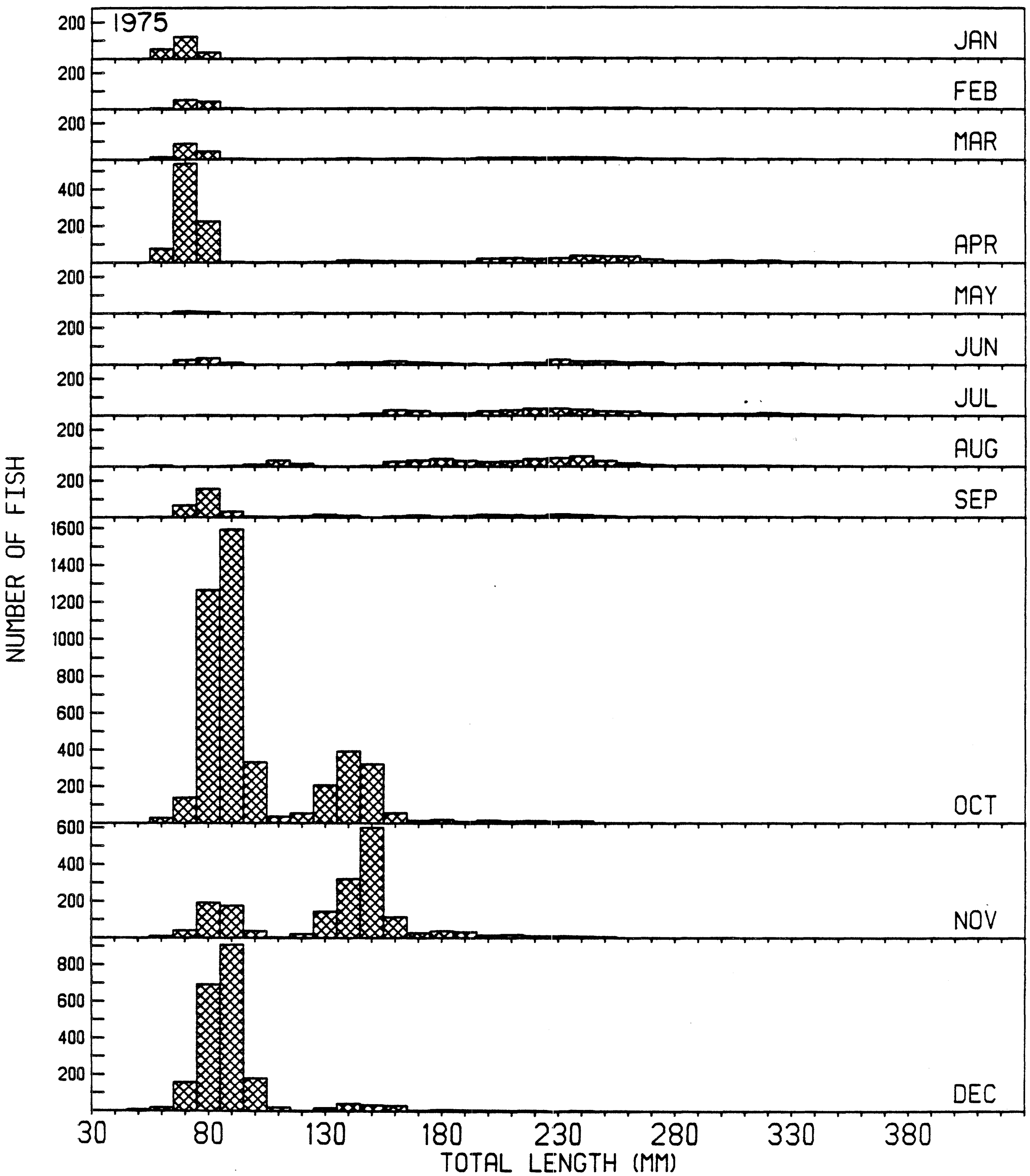
Appendix 54. Length-frequency histograms of trout-perch caught during 1981 field sampling at the Cook Plant, southeastern Lake Michigan.



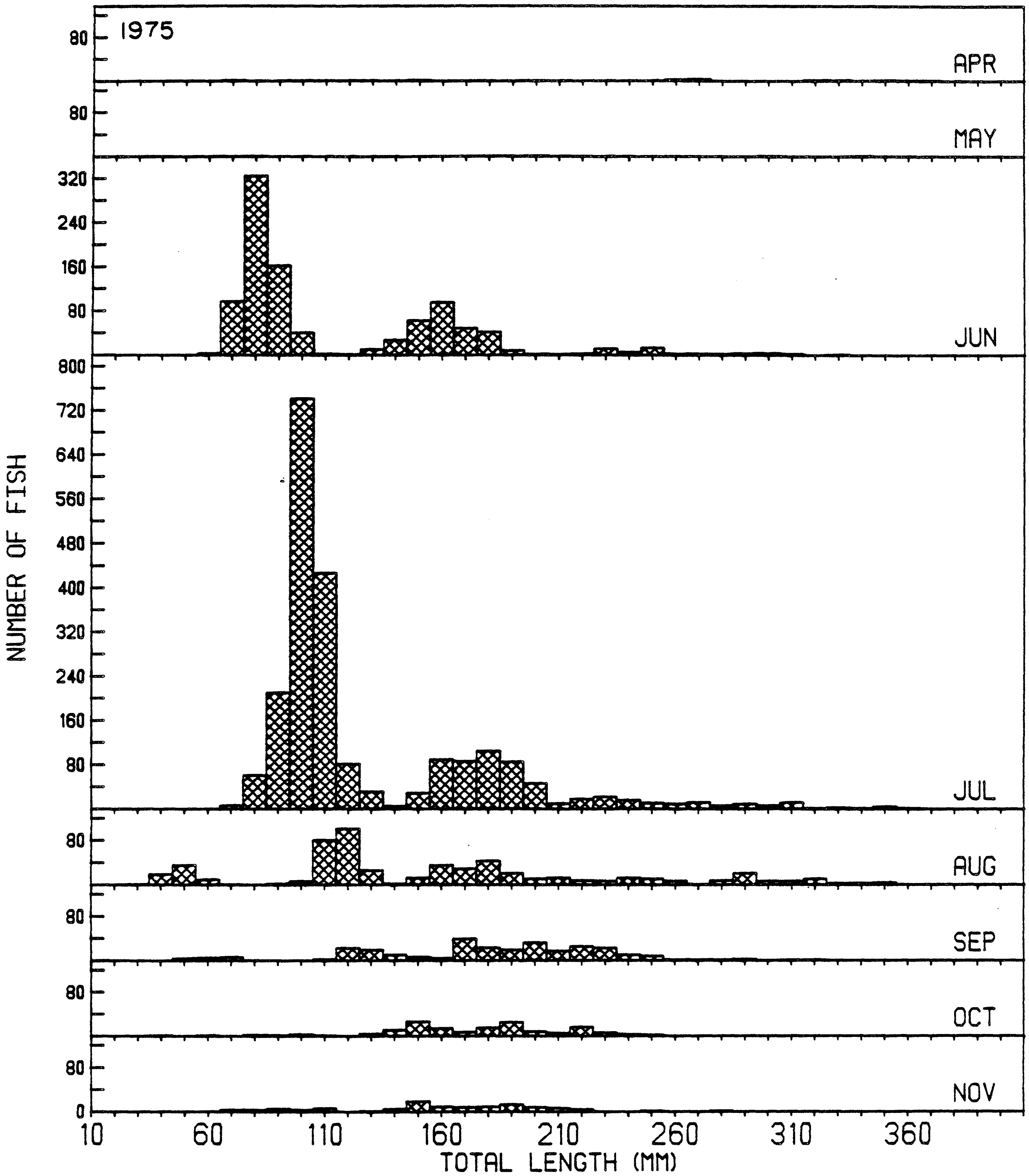
Appendix 55. Length-frequency histograms of trout-perch impinged during 1982 at the Cook Plant, southeastern Lake Michigan.



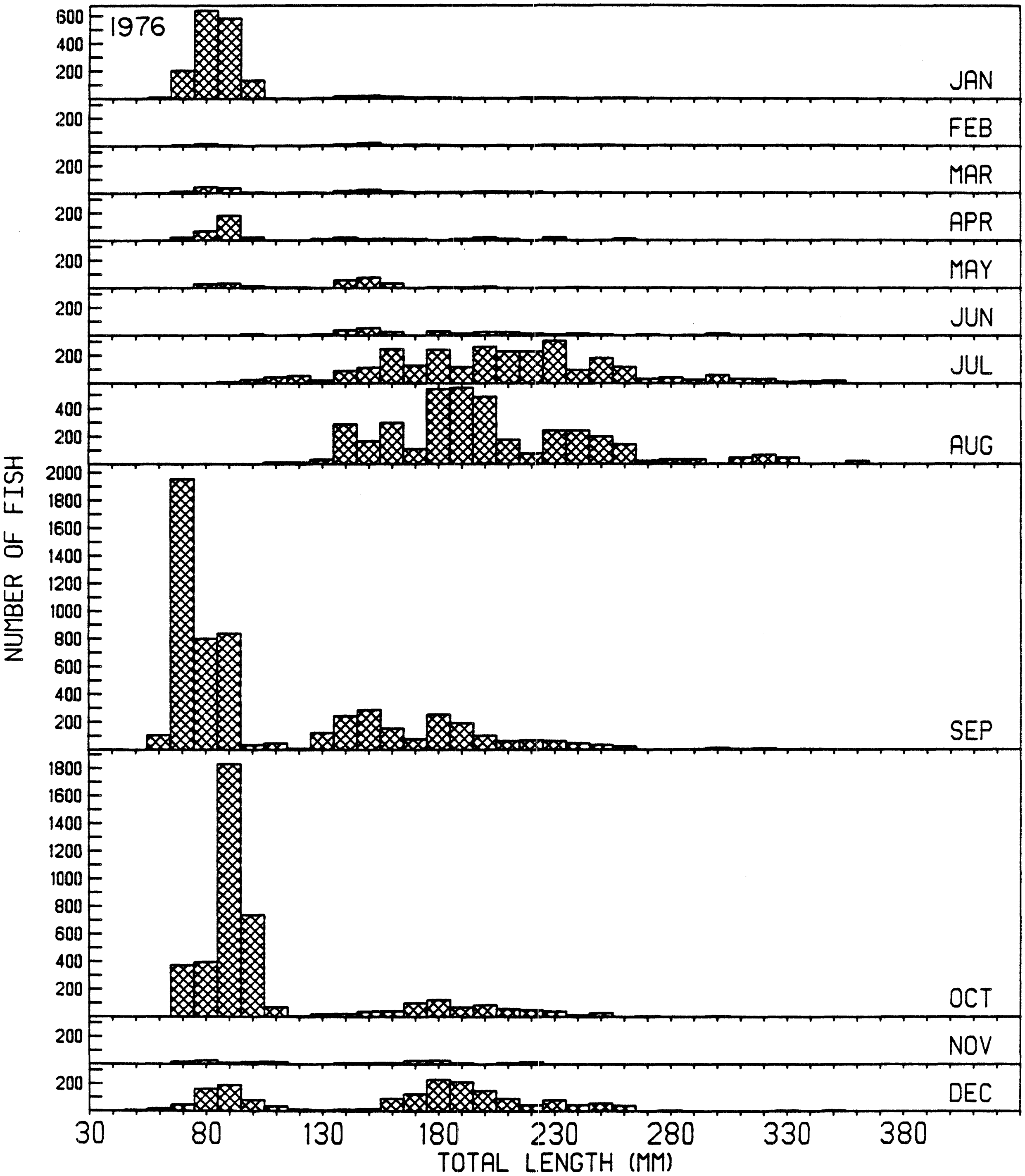
Appendix 56. Length-frequency histograms of trout-perch caught during 1982 field sampling at the Cook Plant, southeastern Lake Michigan.



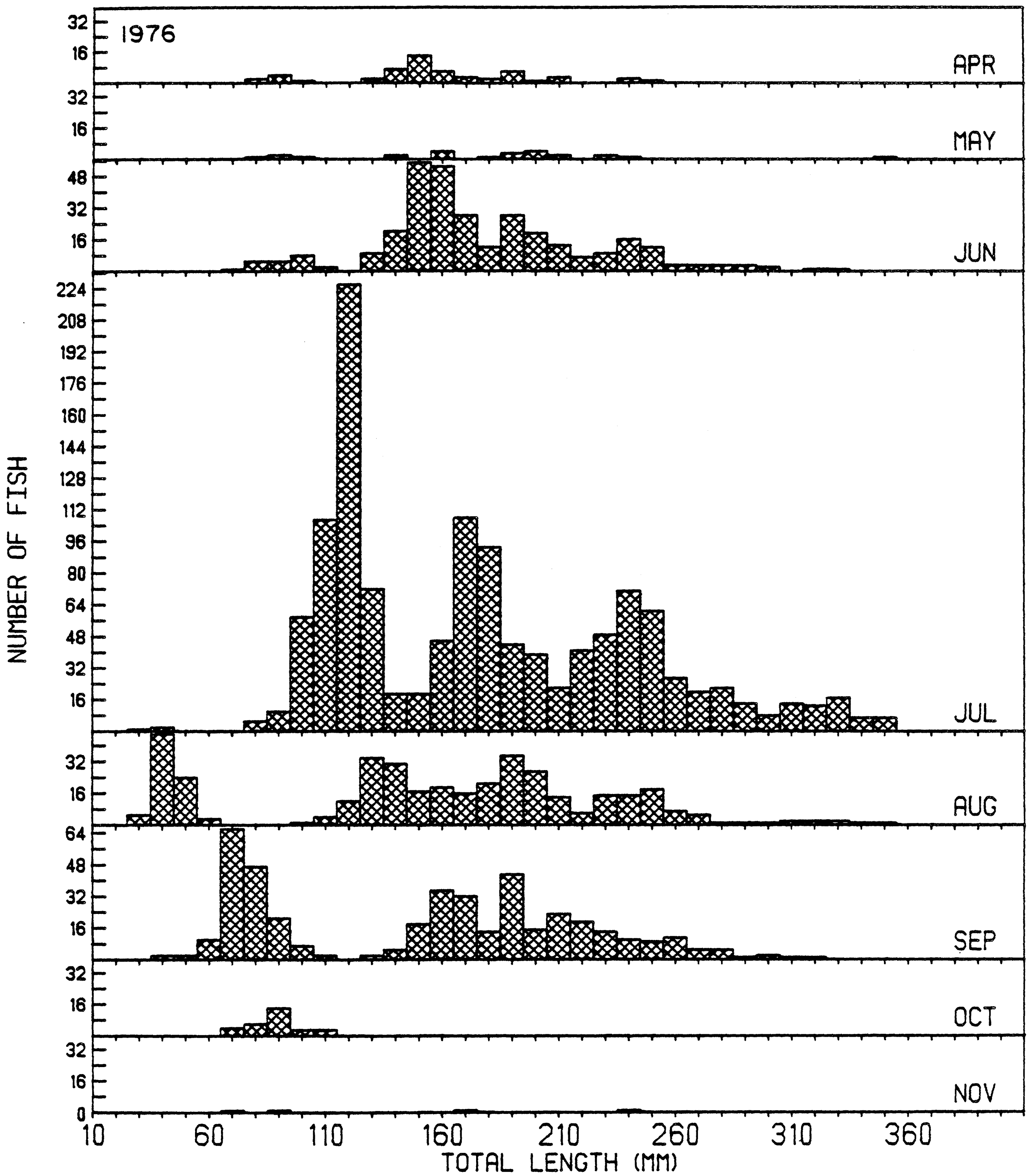
Appendix 57. Length-frequency histograms of yellow perch impinged during 1975 at the Cook Plant, southeastern Lake Michigan.



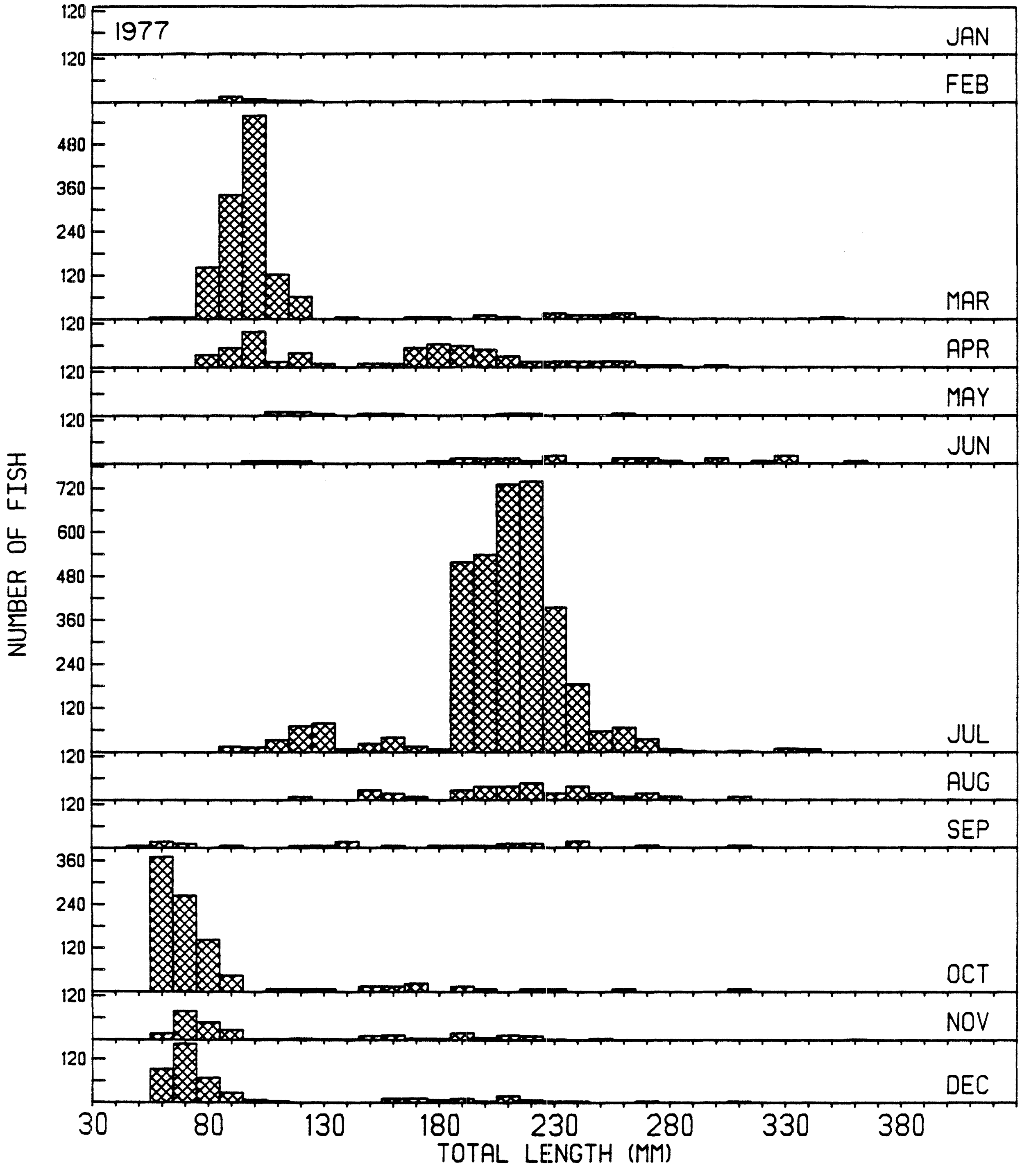
Appendix 58. Length-frequency histograms of yellow perch caught during 1975 field sampling at the Cook Plant, southeastern Lake Michigan.



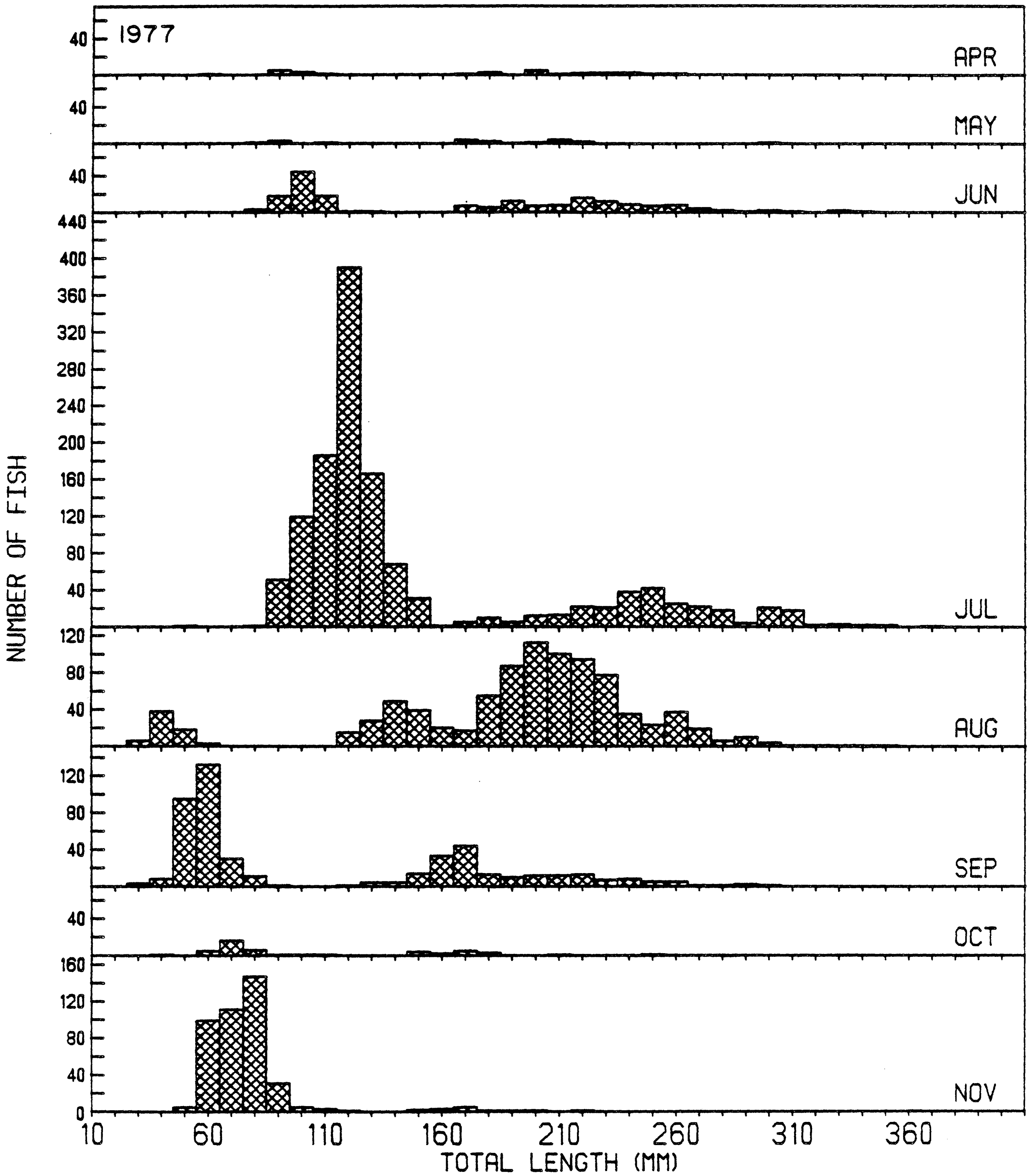
Appendix 59. Length-frequency histograms of yellow perch impinged during 1976 at the Cook Plant, southeastern Lake Michigan.



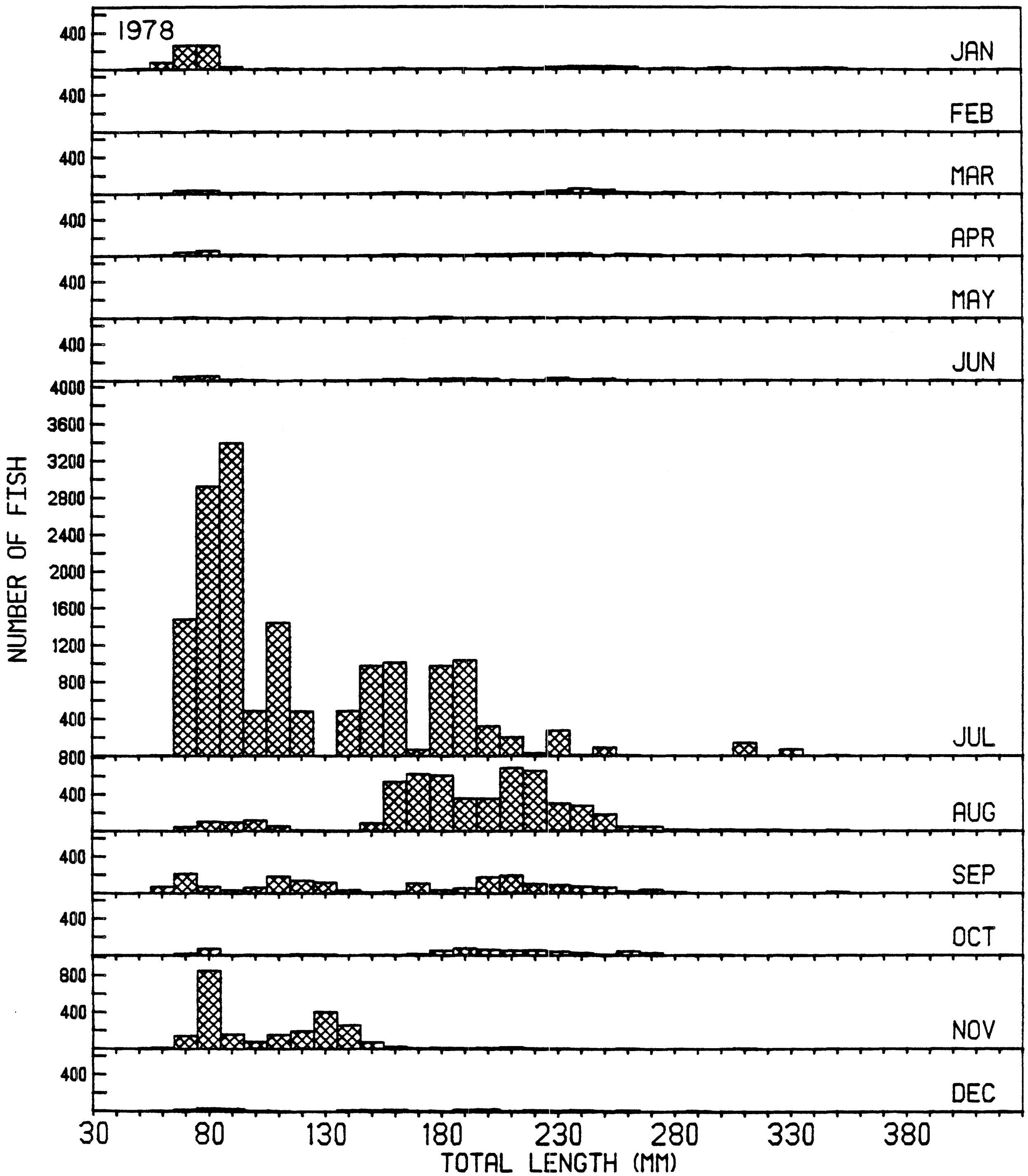
Appendix 60. Length-frequency histograms of yellow perch caught during 1976 field sampling at the Cook Plant, southeastern Lake Michigan.



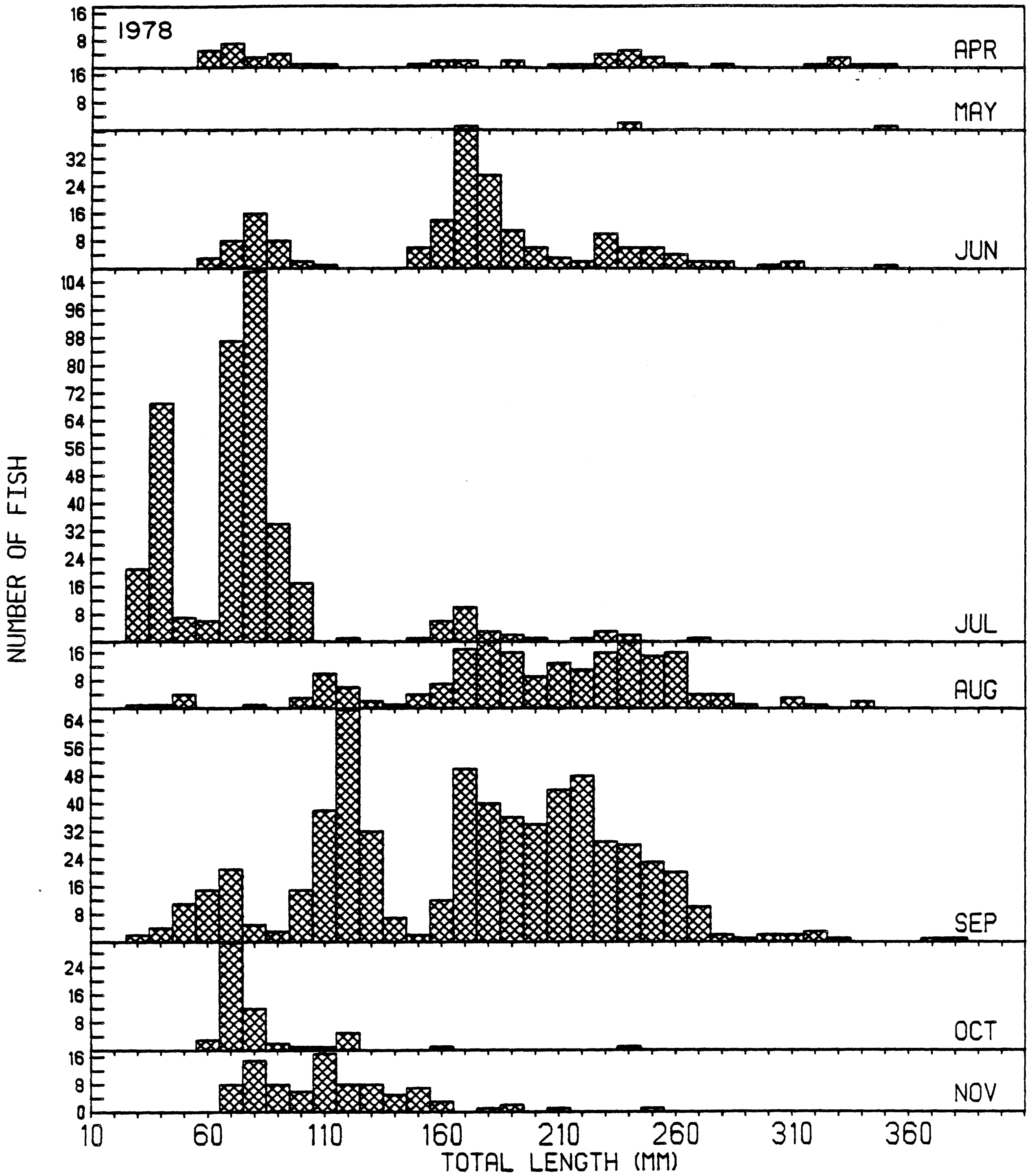
Appendix 61. Length-frequency histograms of yellow perch impinged during 1977 at the Cook Plant, southeastern Lake Michigan.



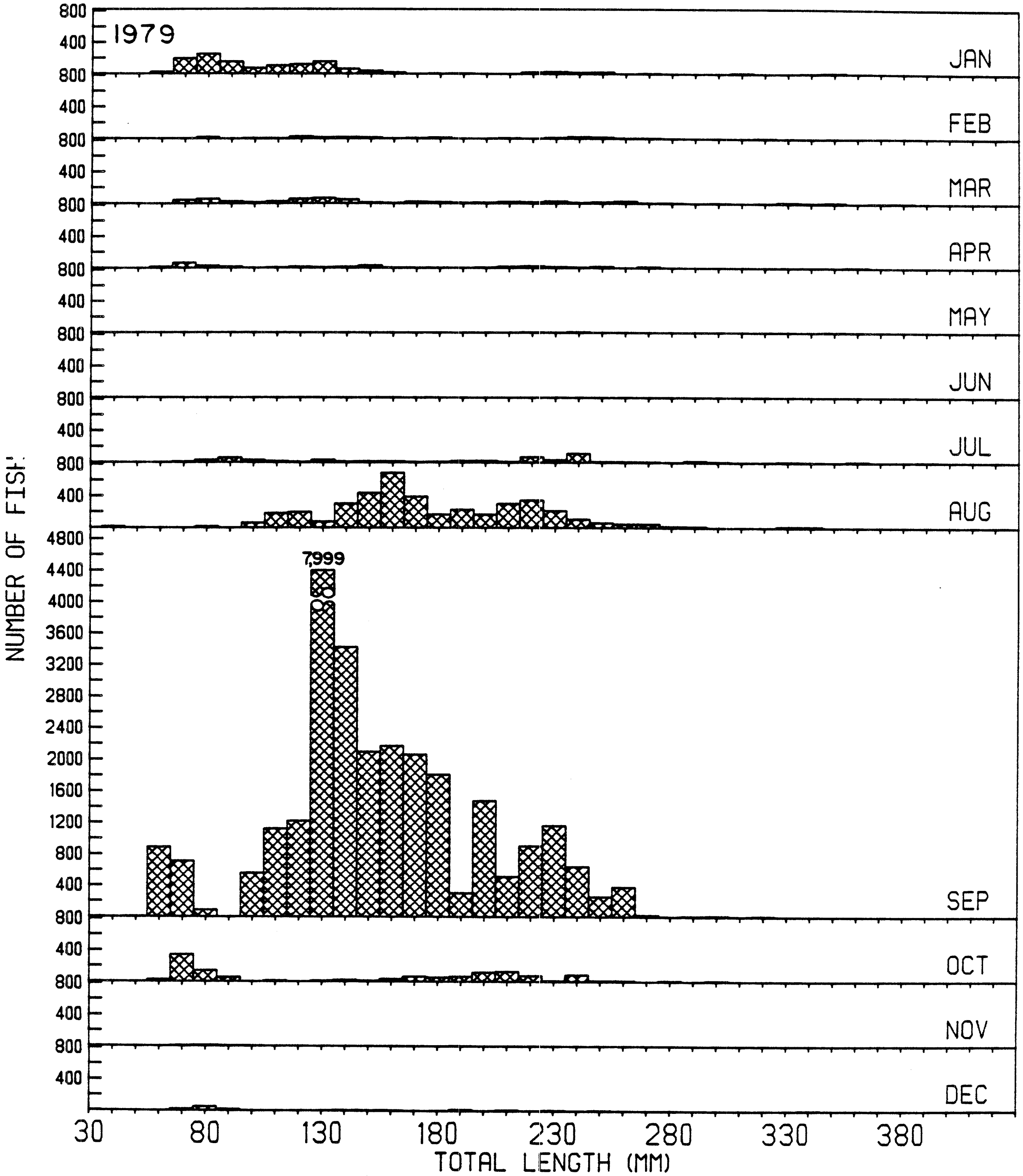
Appendix 62. Length-frequency histograms of yellow perch caught during 1977 field sampling at the Cook Plant, southeastern Lake Michigan.



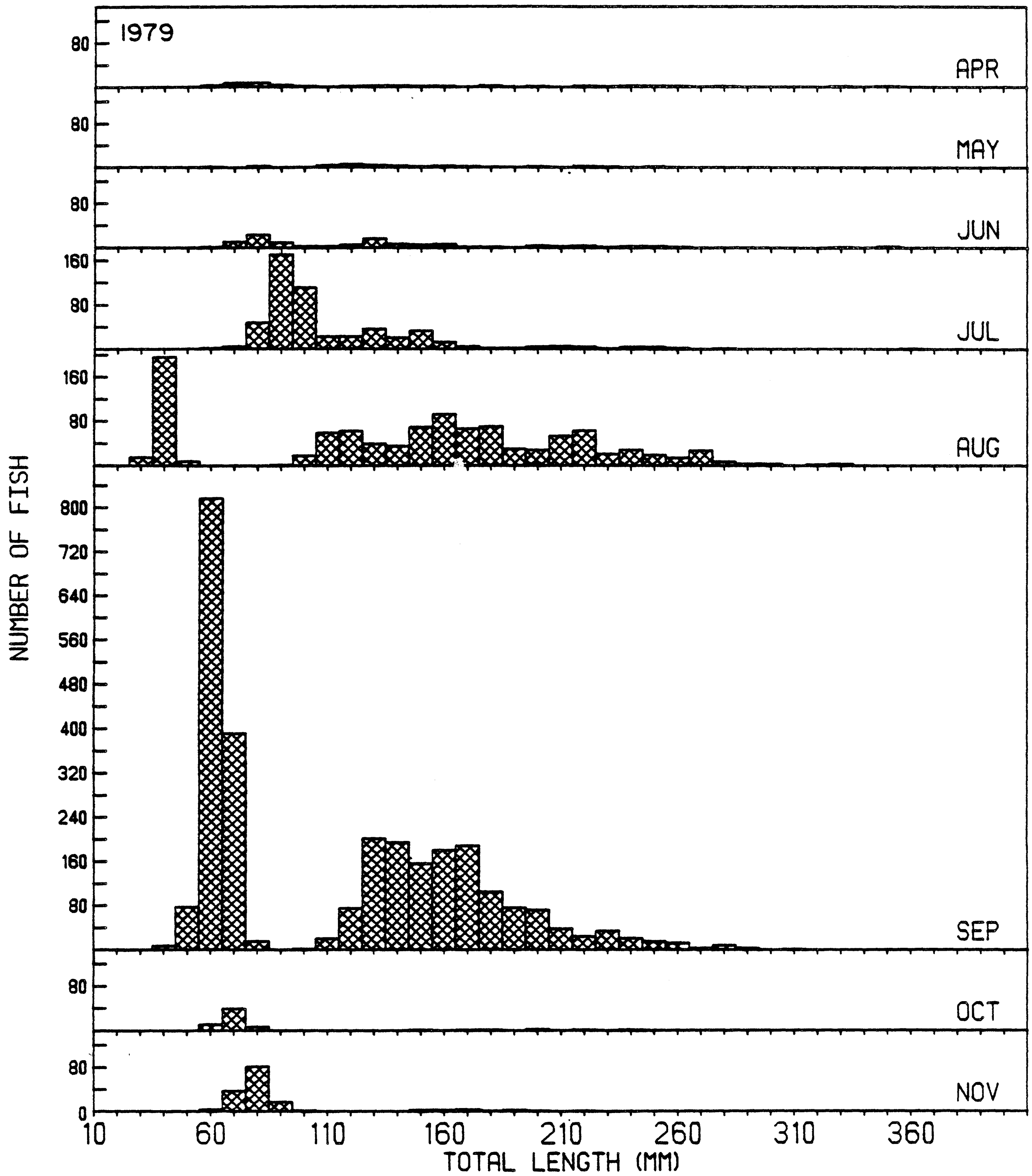
Appendix 63. Length-frequency histograms of yellow perch impinged during 1978 at the Cook Plant, southeastern Lake Michigan.



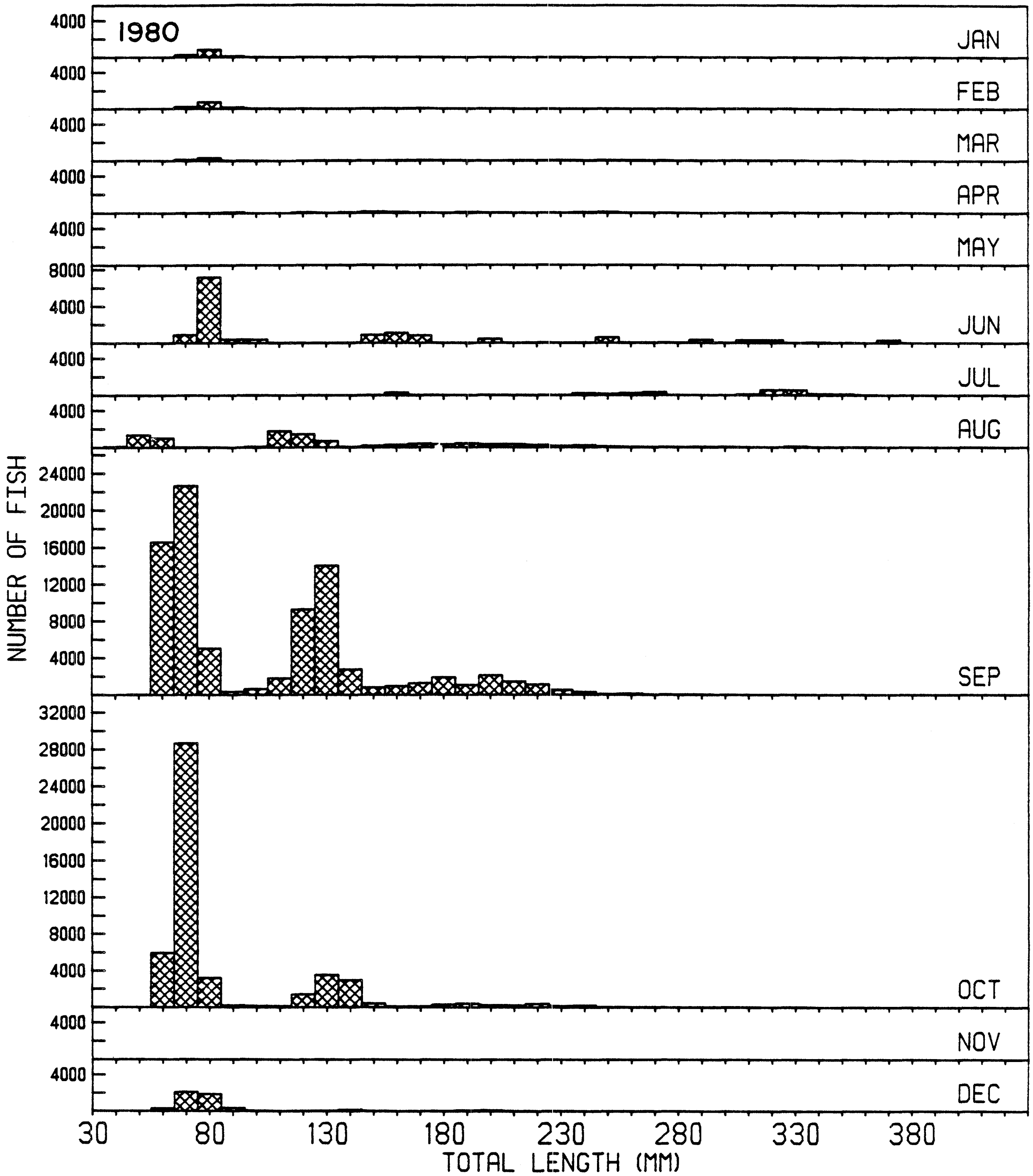
Appendix 64. Length-frequency histograms of yellow perch caught during 1978 field sampling at the Cook Plant, southeastern Lake Michigan.



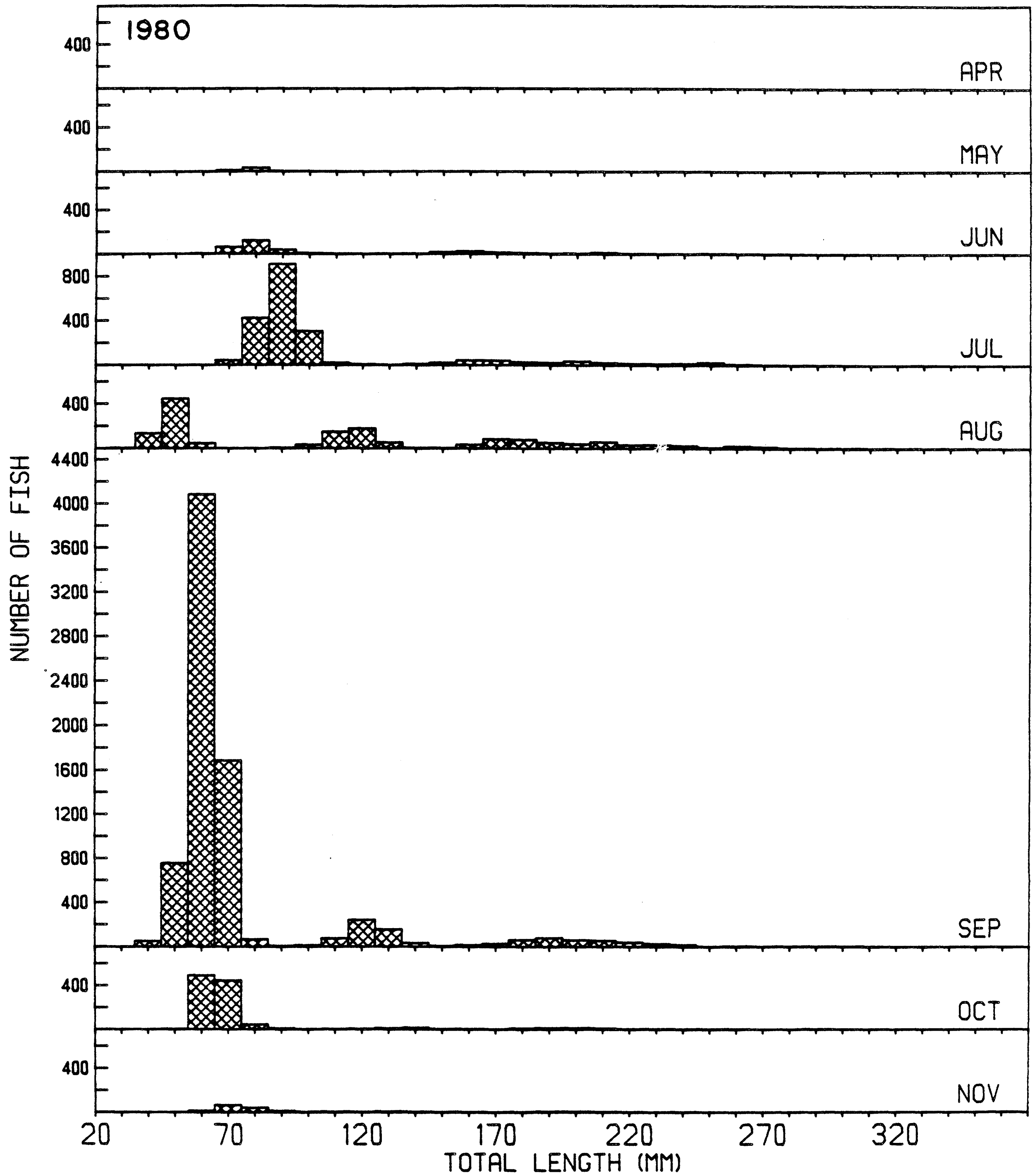
Appendix 65. Length-frequency histograms of yellow perch impinged during 1979 at the Cook Plant, southeastern Lake Michigan.



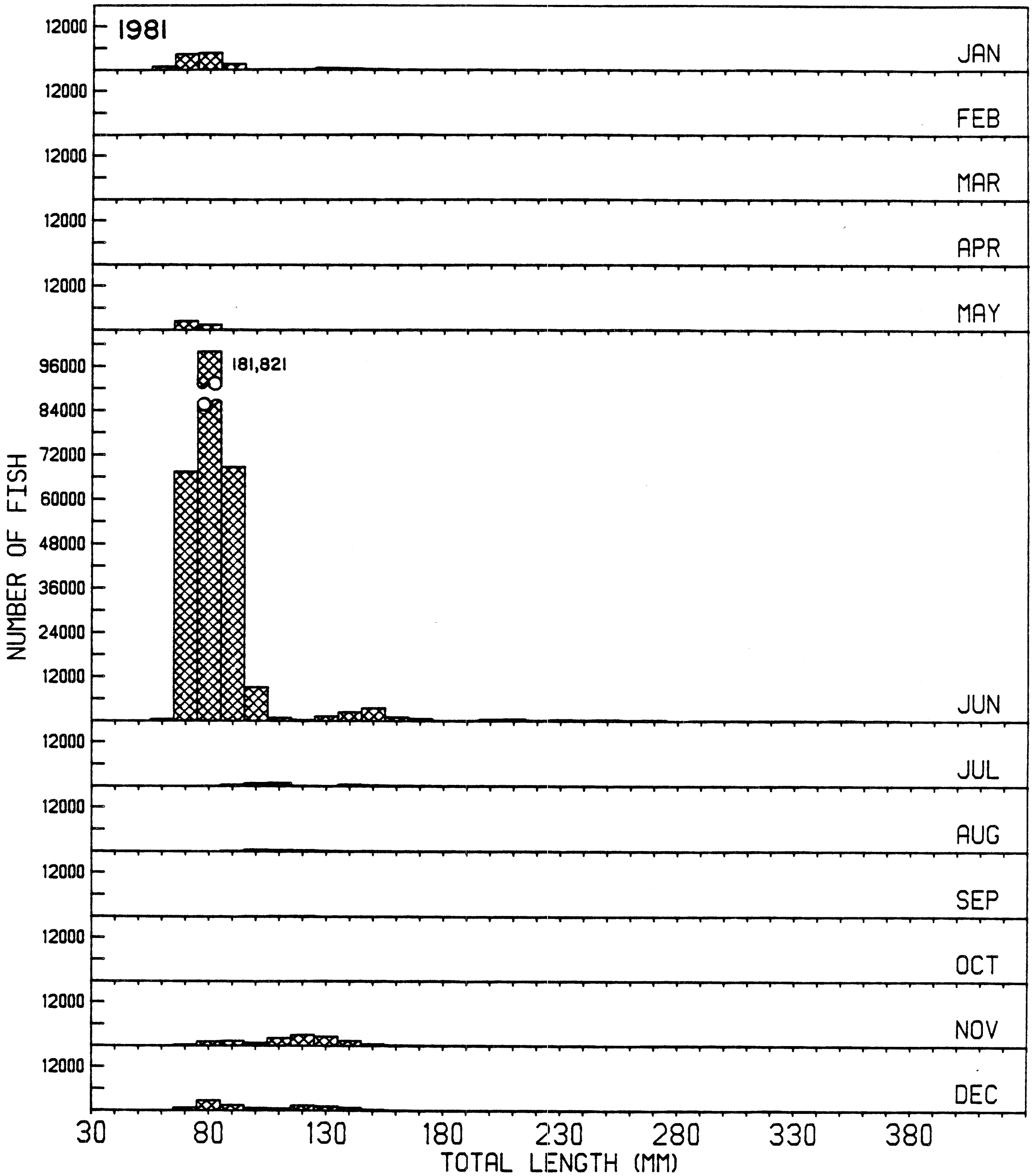
Appendix 66. Length-frequency histograms of yellow perch caught during 1979 field sampling at the Cook Plant, southeastern Lake Michigan.



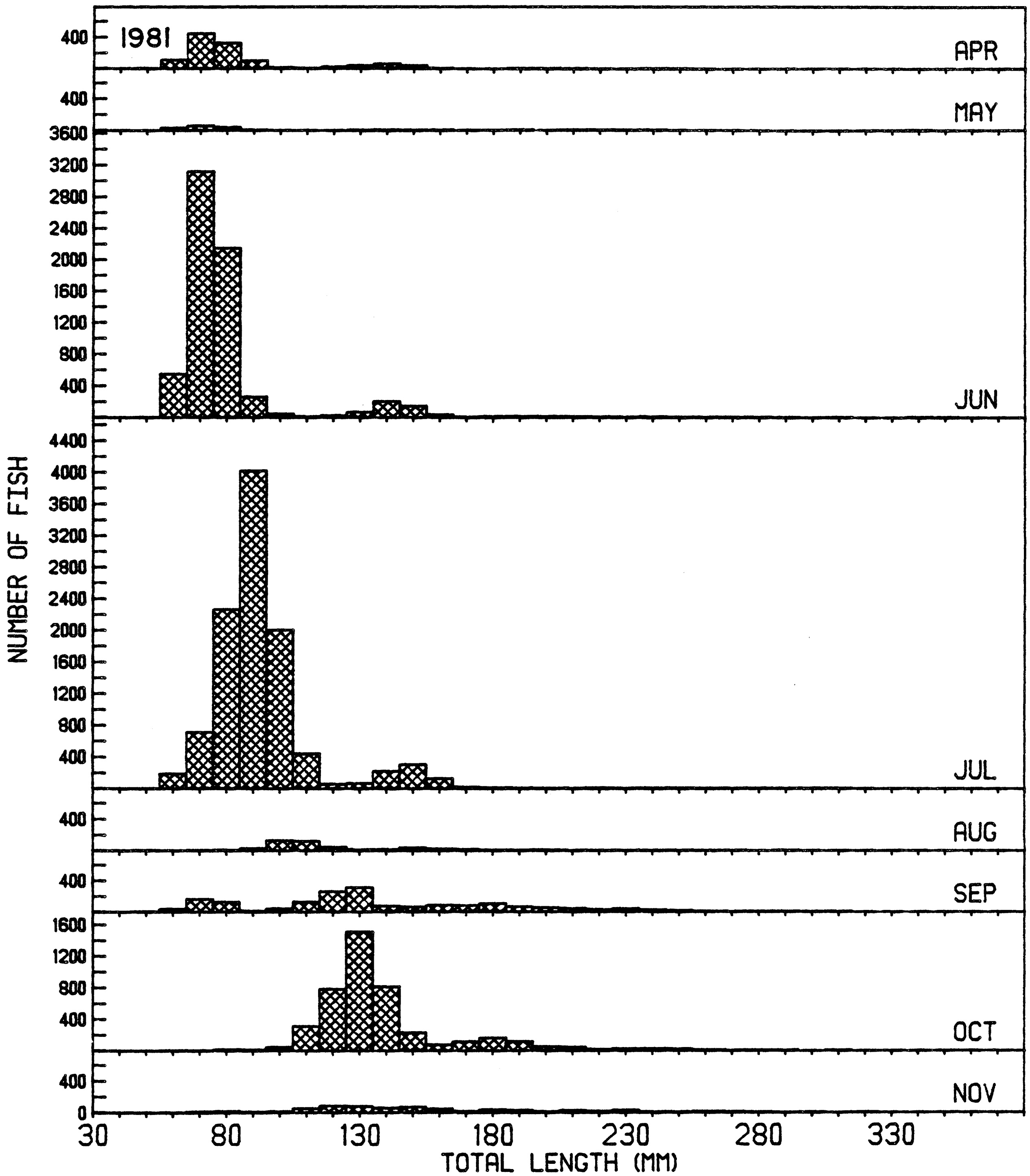
Appendix 67. Length-frequency histograms of yellow perch impinged during 1980 at the Cook Plant, southeastern Lake Michigan.



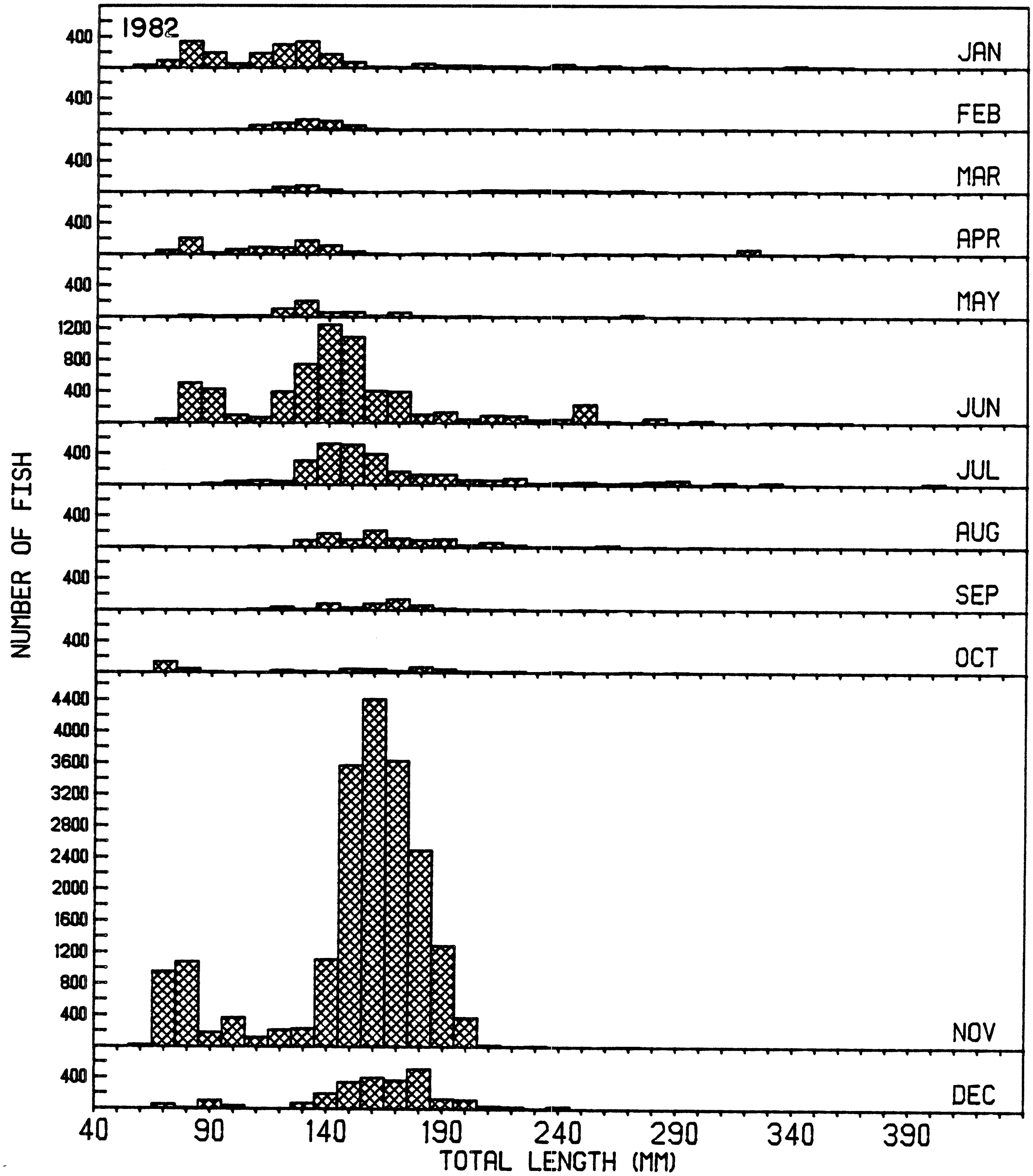
Appendix 68. Length-frequency histograms of yellow perch caught during 1980 field sampling at the Cook Plant, southeastern Lake Michigan.



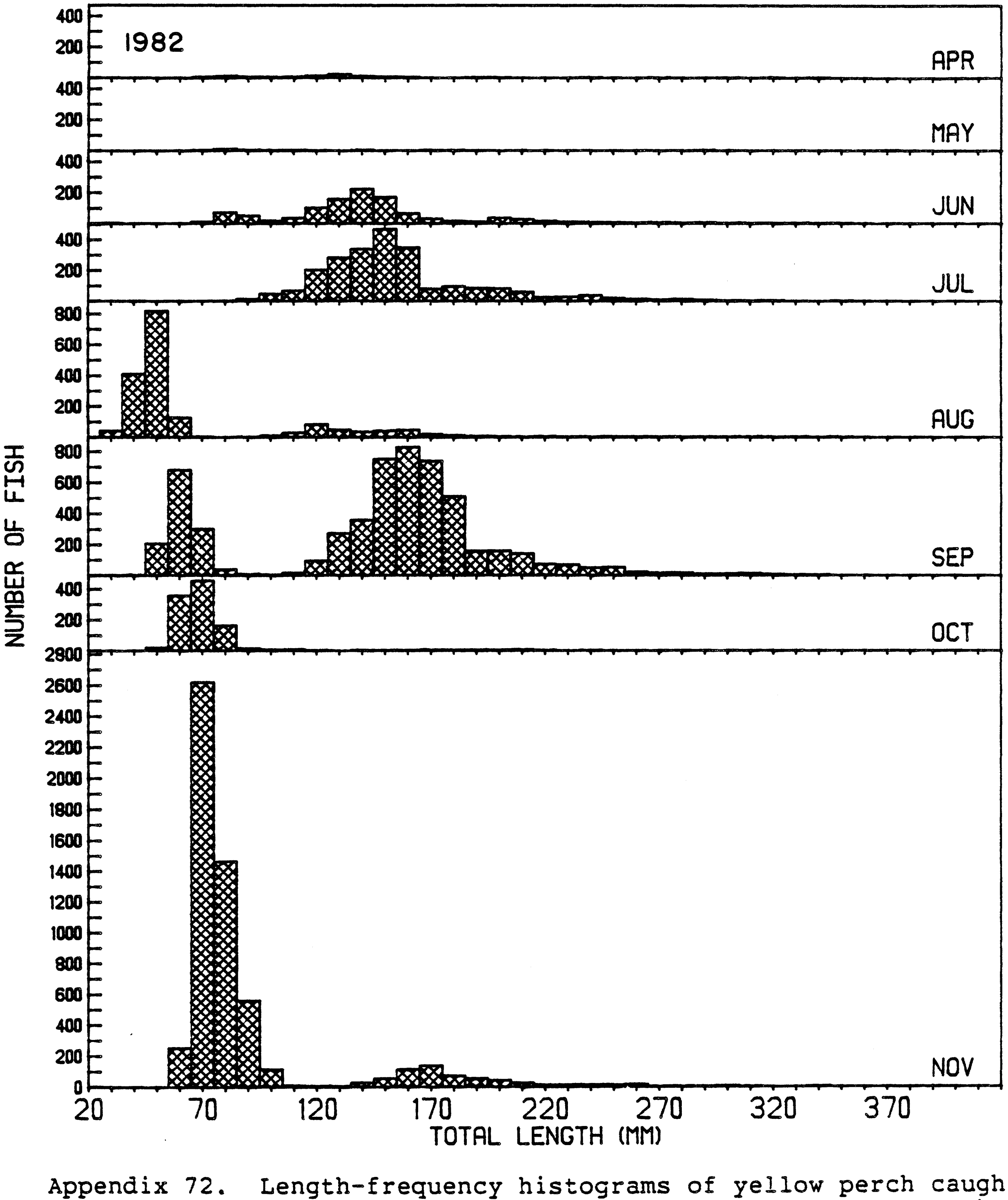
Appendix 69. Length-frequency histograms of yellow perch impinged during 1981 at the Cook Plant, southeastern Lake Michigan.



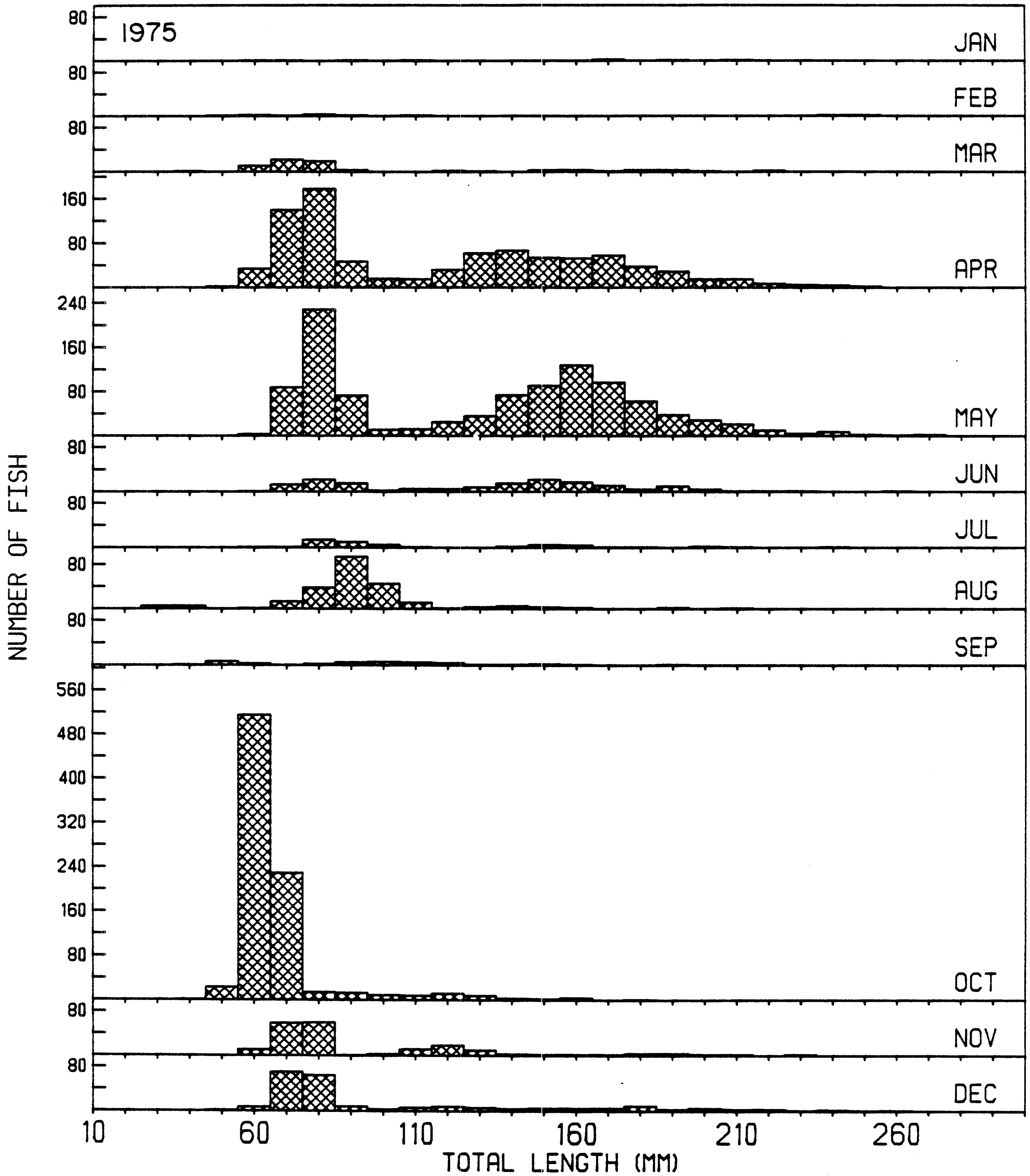
Appendix 70. Length-frequency histograms of yellow perch caught during 1981 field sampling at the Cook Plant, southeastern Lake Michigan.



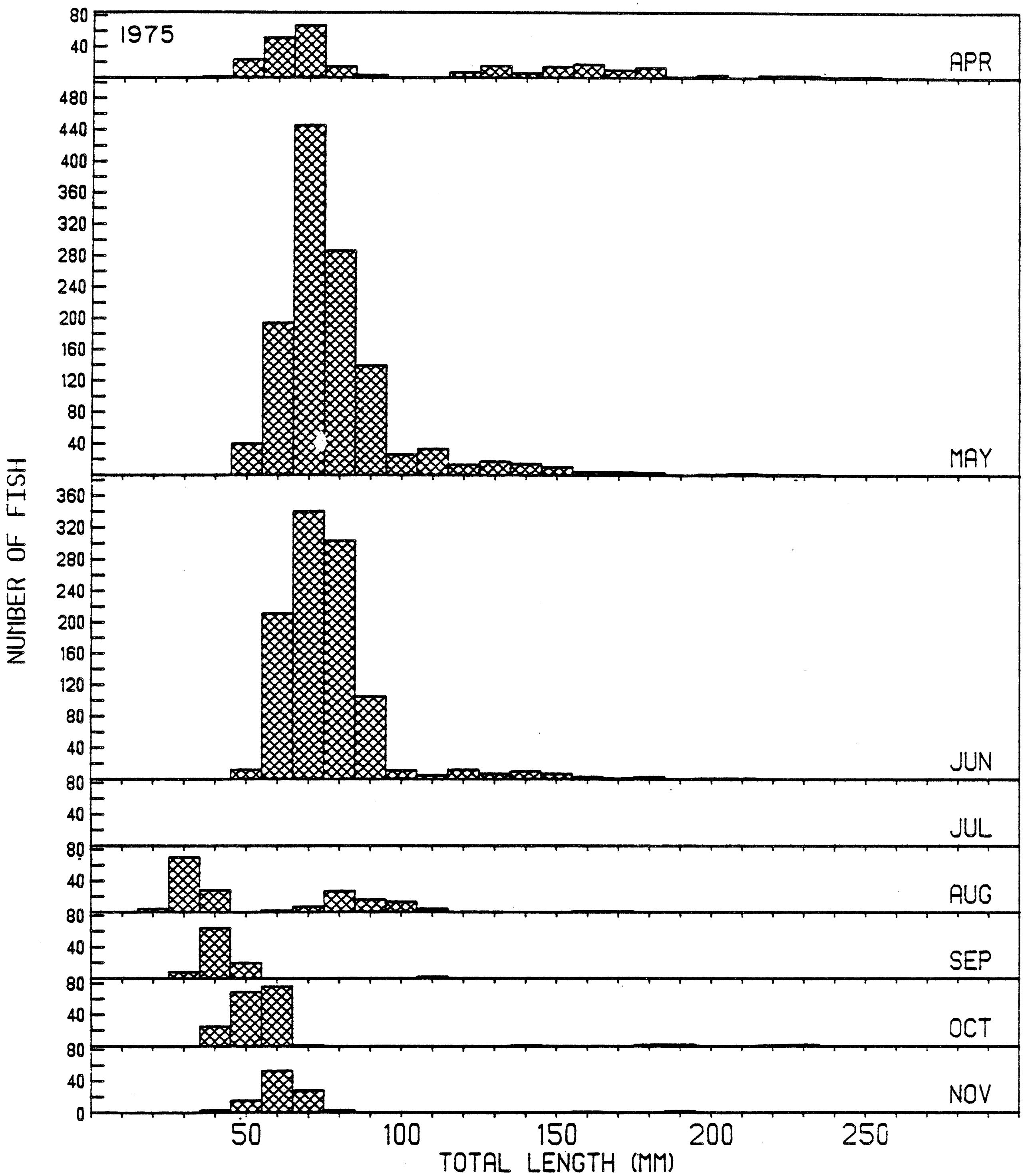
Appendix 71. Length-frequency histograms of yellow perch impinged during 1982 at the Cook Plant, southeastern Lake Michigan.



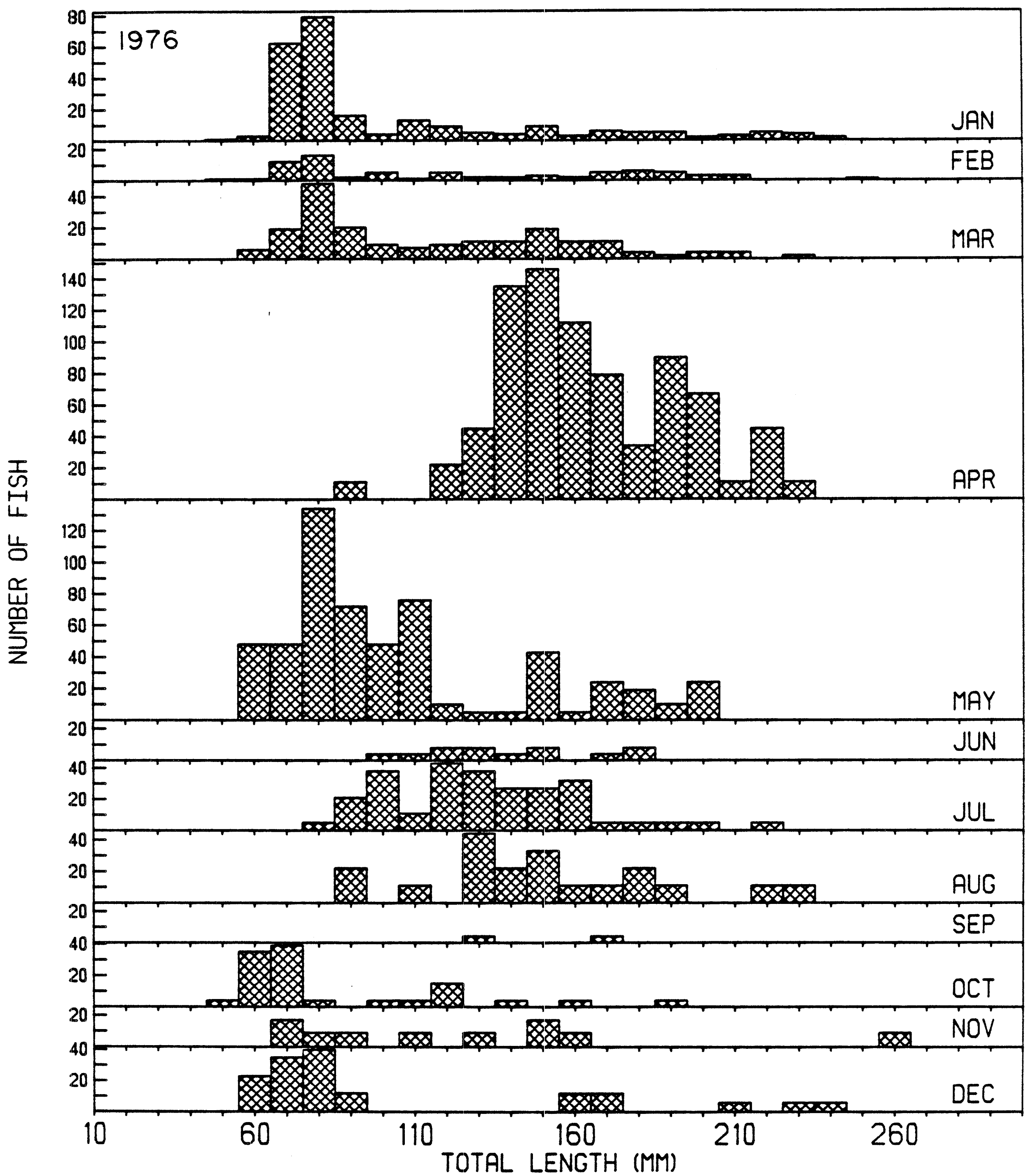
Appendix 72. Length-frequency histograms of yellow perch caught during 1982 field sampling at the Cook Plant, southeastern Lake Michigan.



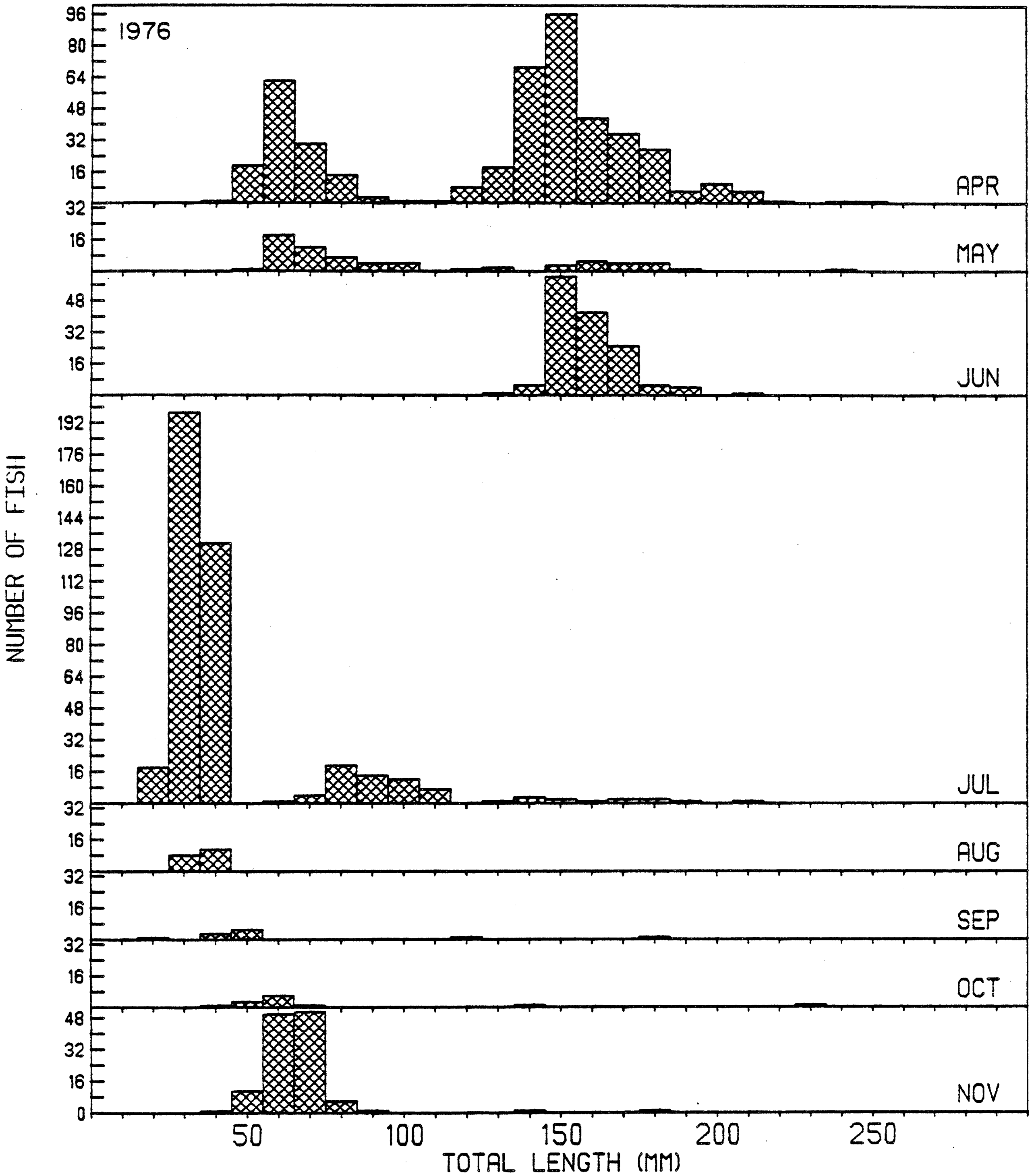
Appendix 73. Length-frequency histograms of rainbow smelt impinged during 1975 at the Cook Plant, southeastern Lake Michigan.



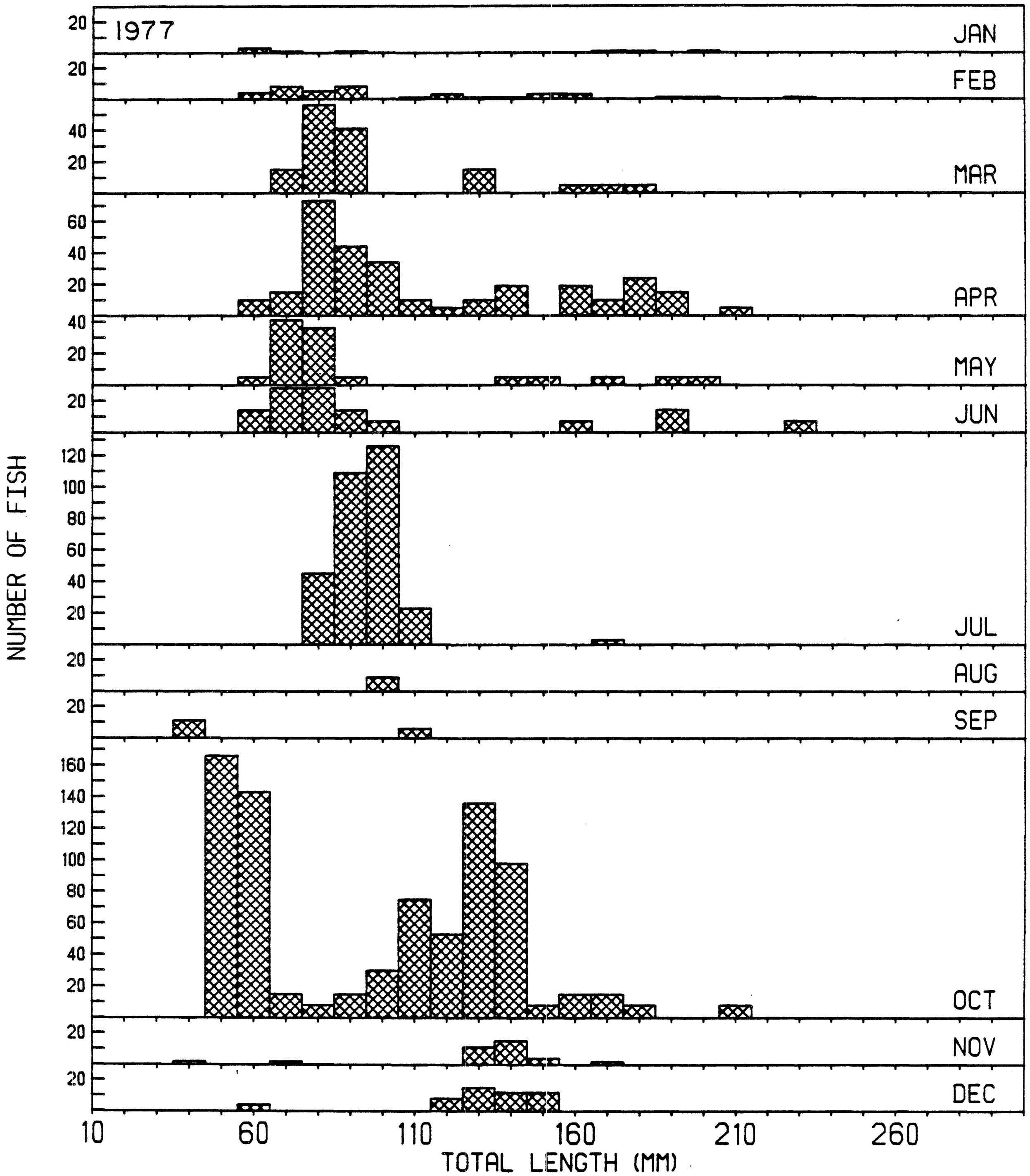
Appendix 74. Length-frequency histograms of rainbow smelt caught during 1975 field sampling at the Cook Plant, southeastern Lake Michigan.



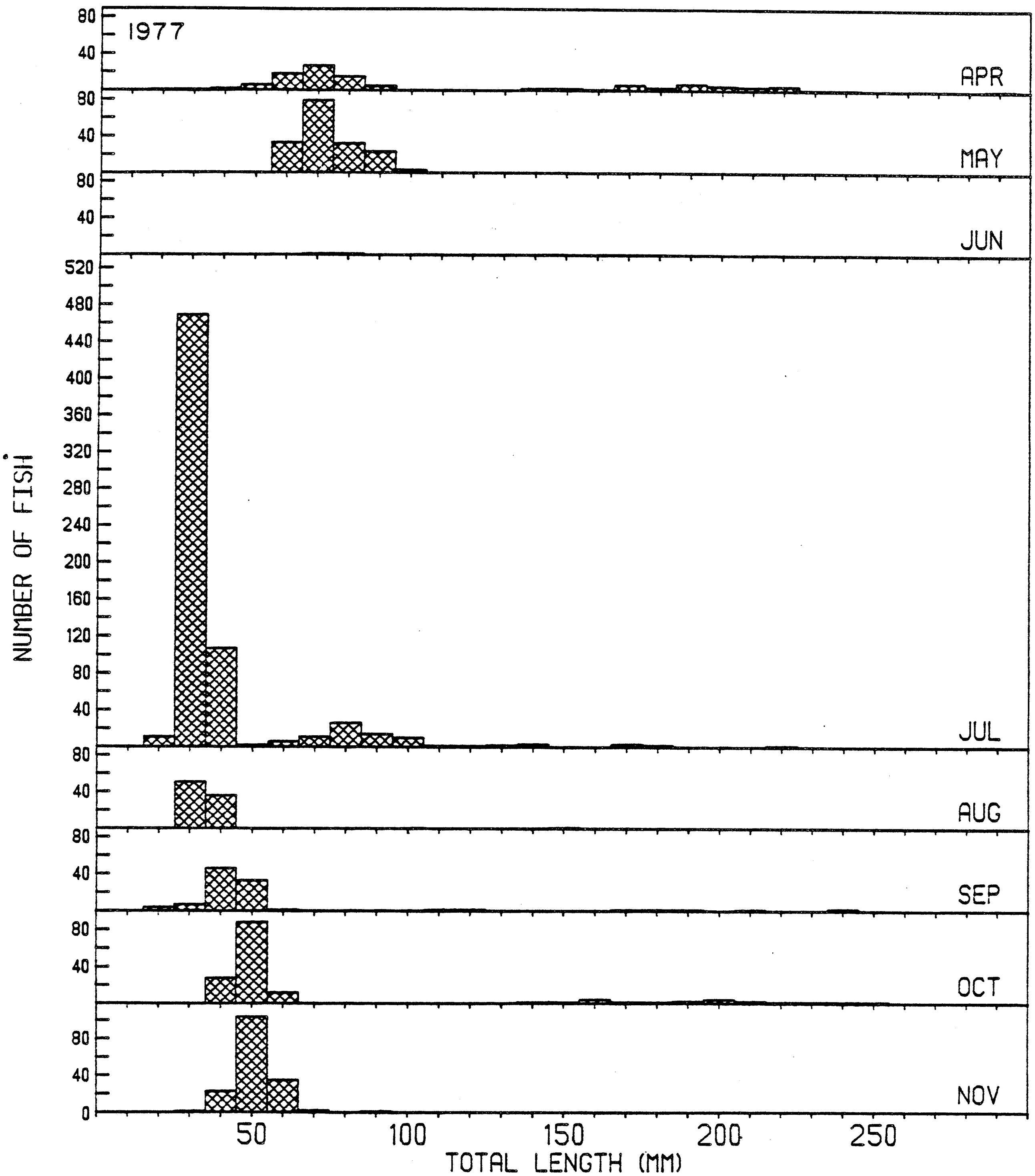
Appendix 75. Length-frequency histograms of rainbow smelt impinged during 1976 at the Cook Plant, southeastern Lake Michigan.



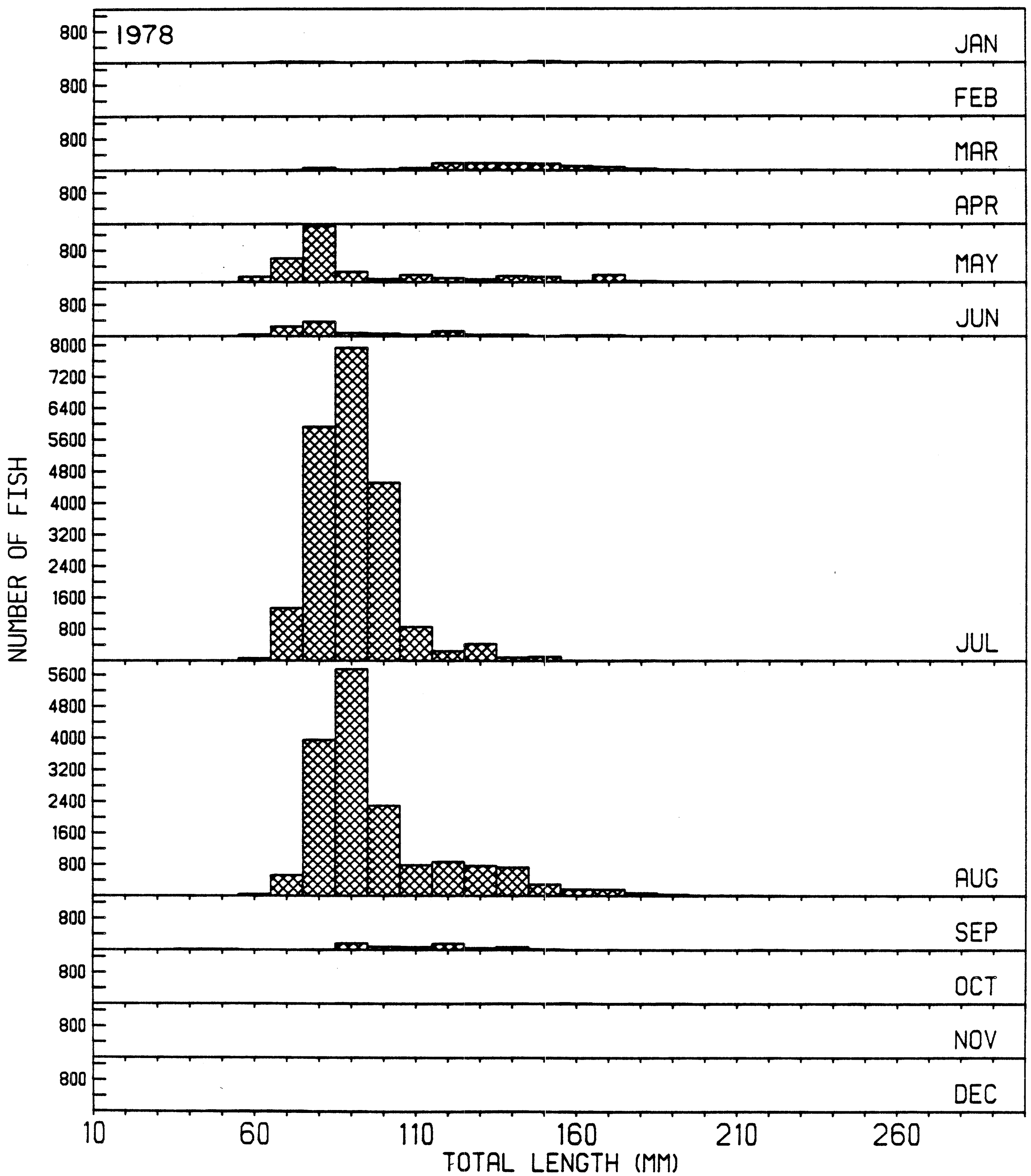
Appendix 76. Length-frequency histograms of rainbow smelt caught during 1976 field sampling at the Cook Plant, southeastern Lake Michigan.



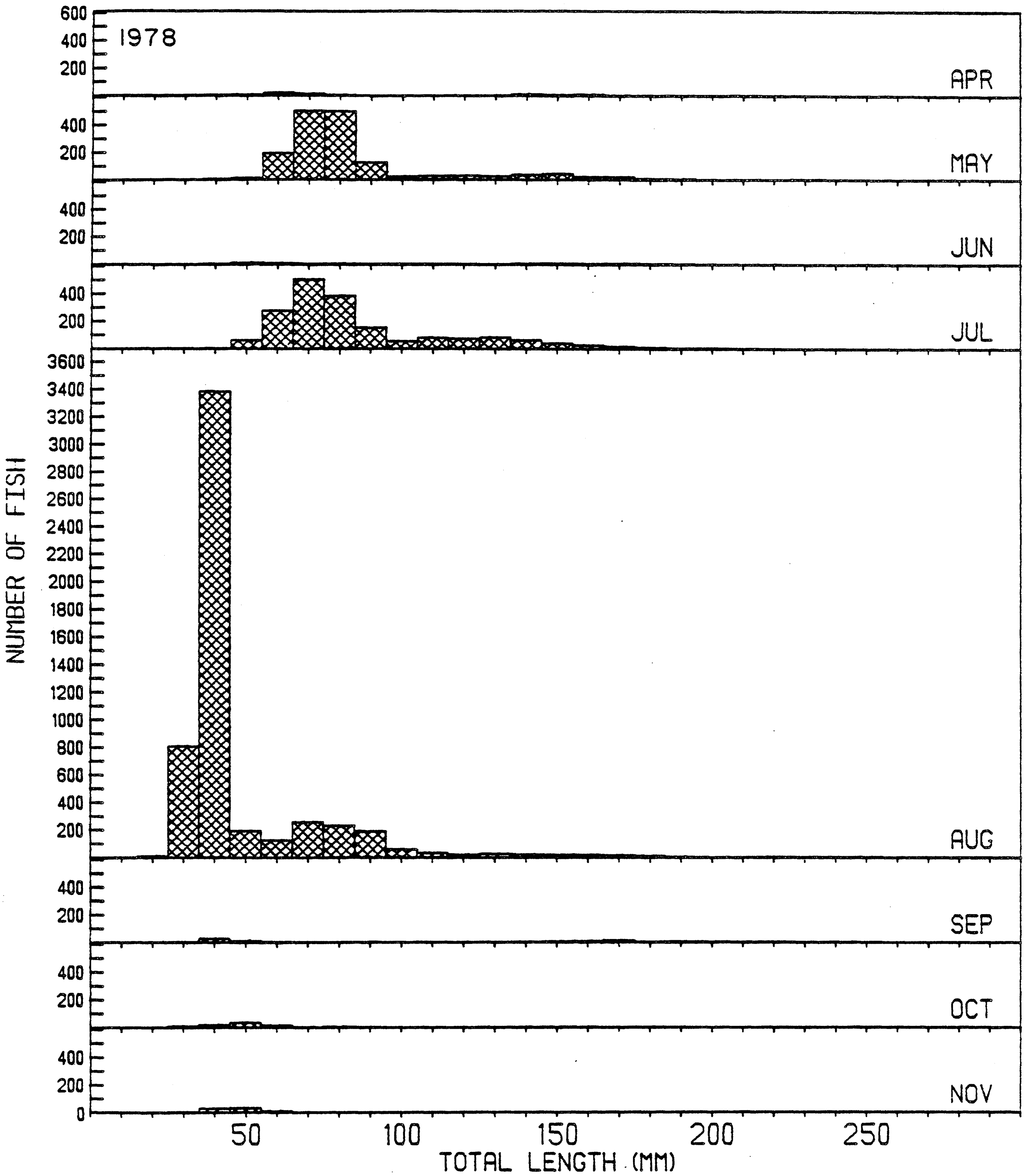
Appendix 77. Length-frequency histograms of rainbow smelt impinged during 1977 at the Cook Plant, southeastern Lake Michigan.



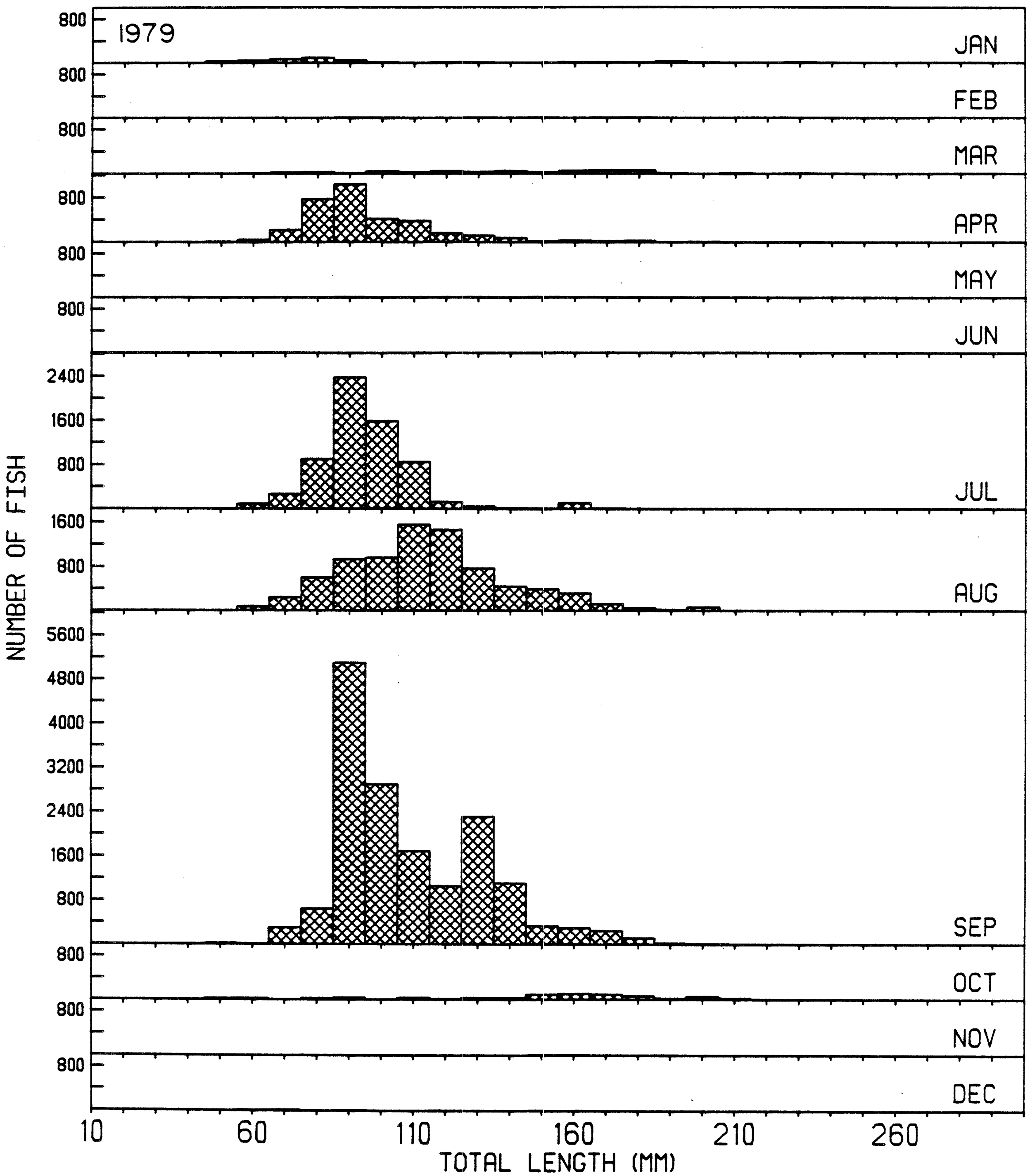
Appendix 78. Length-frequency histograms of rainbow smelt caught during 1977 field sampling at the Cook Plant, southeastern Lake Michigan.



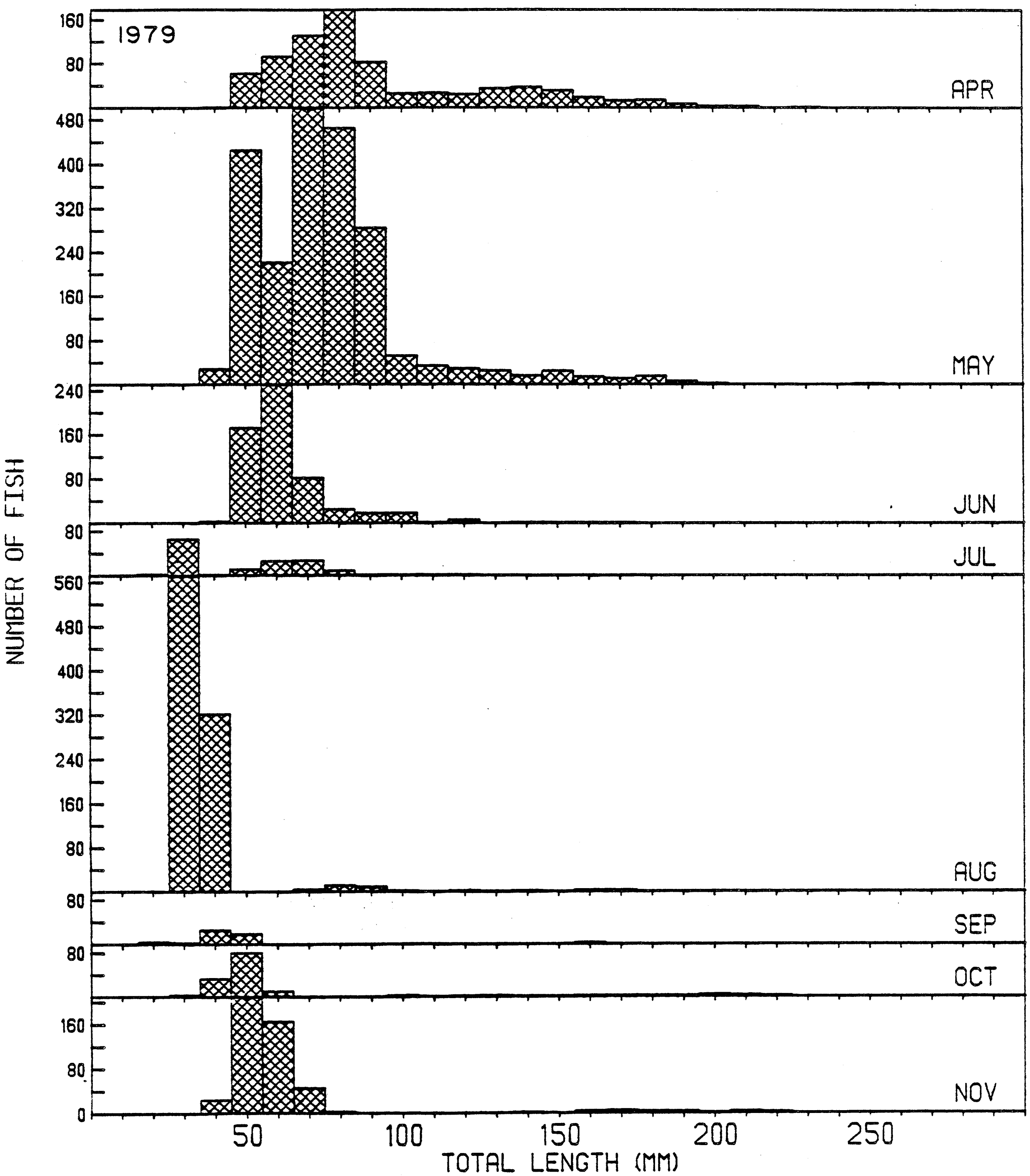
Appendix 79. Length-frequency histograms of rainbow smelt impinged during 1978 at the Cook Plant, southeastern Lake Michigan.



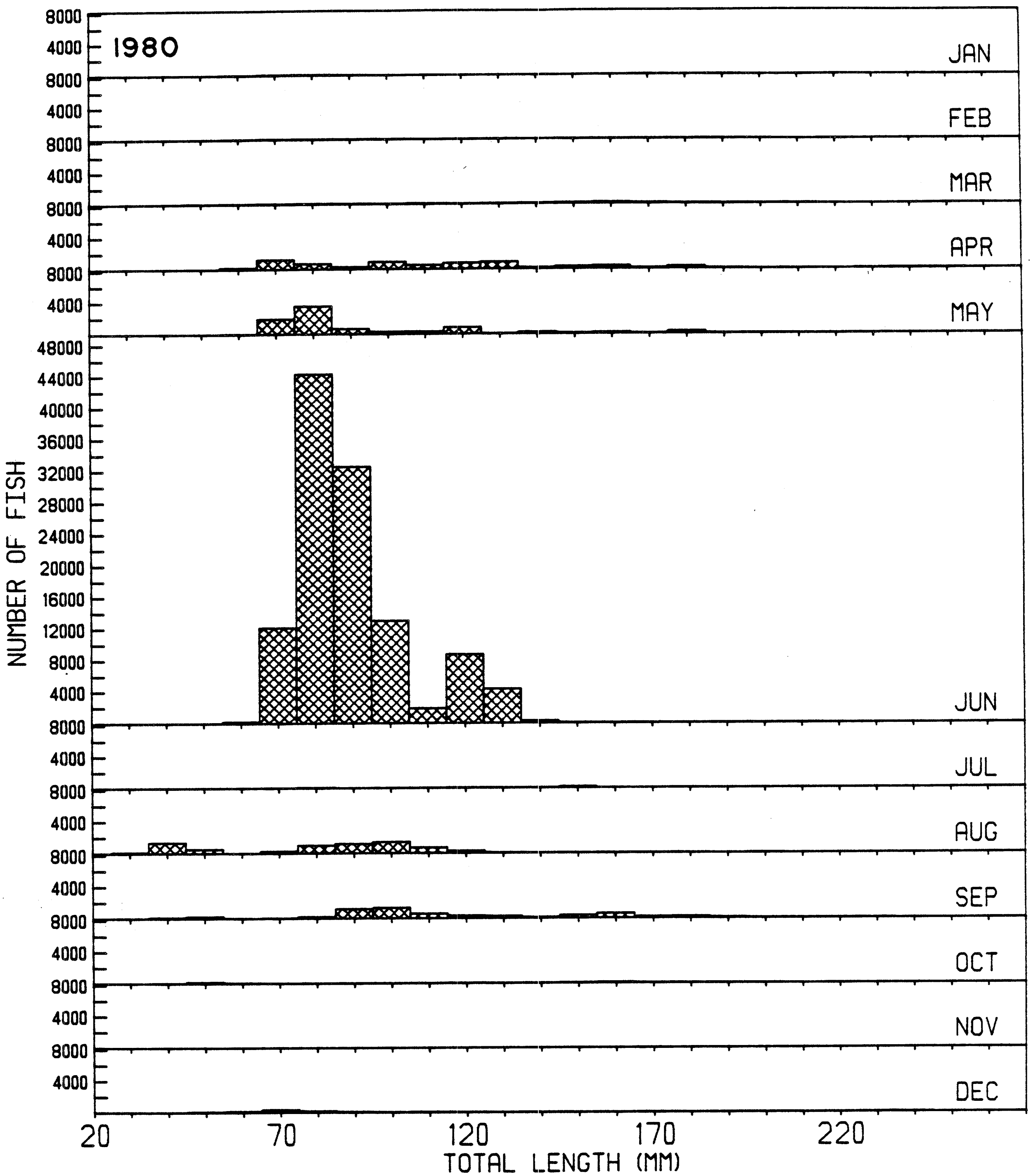
Appendix 80. Length-frequency histograms of rainbow smelt caught during 1978 field sampling at the Cook Plant, southeastern Lake Michigan.



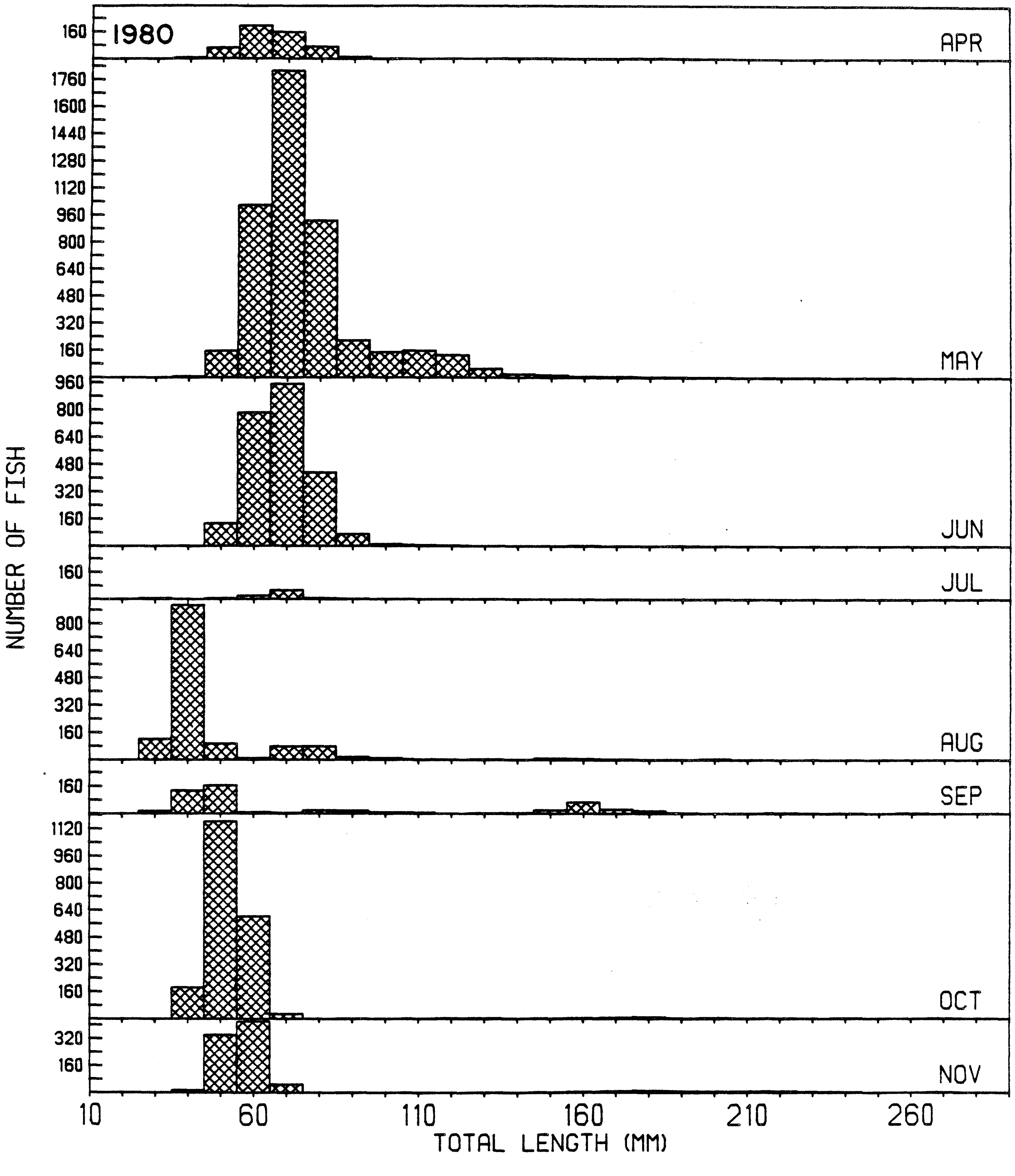
Appendix 81. Length-frequency histograms of rainbow smelt impinged during 1979 at the Cook Plant, southeastern Lake Michigan.



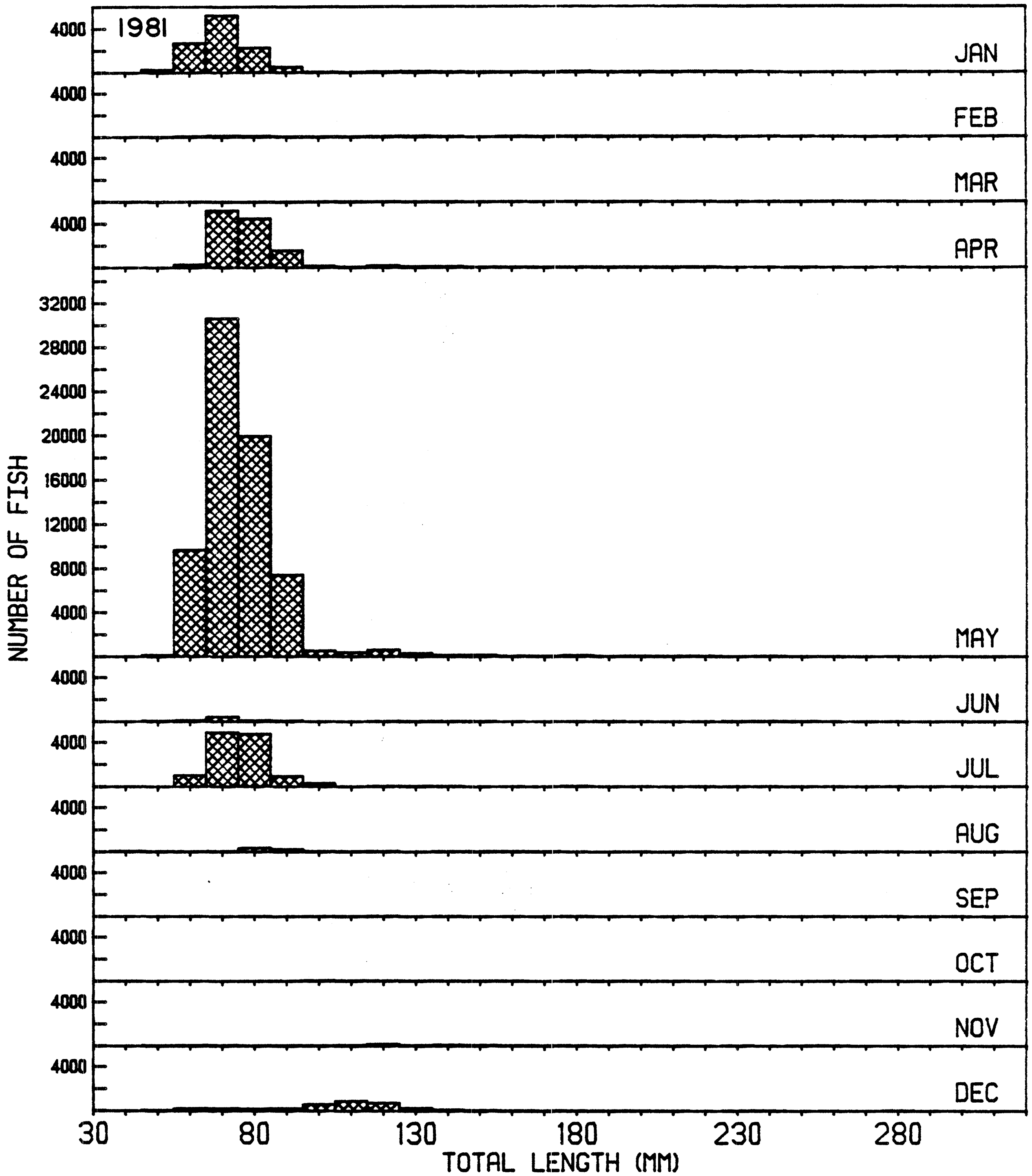
Appendix 82. Length-frequency histograms of rainbow smelt caught during 1979 field sampling at the Cook Plant, southeastern Lake Michigan.



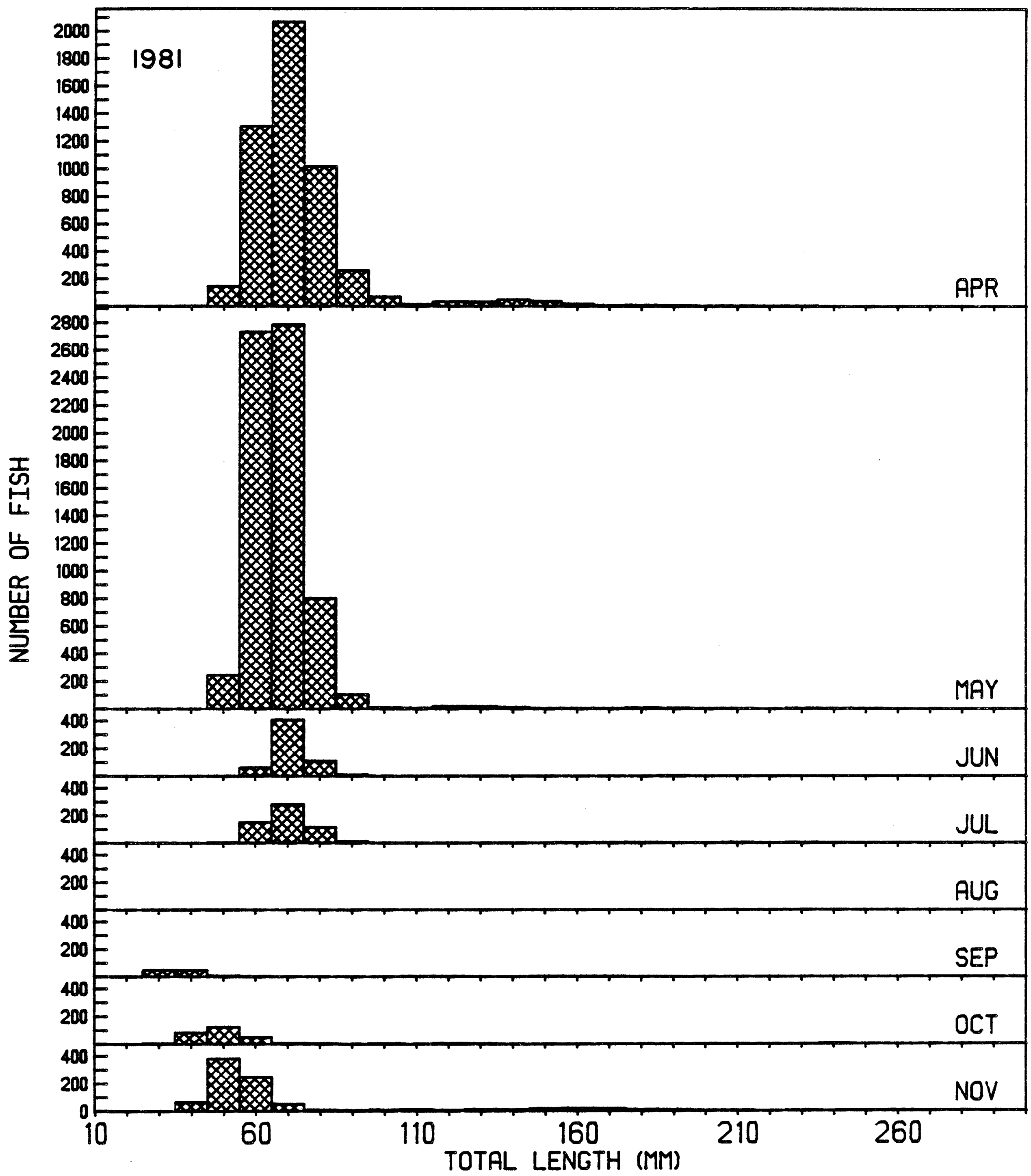
Appendix 83. Length-frequency histograms of rainbow smelt impinged during 1980 at the Cook Plant, southeastern Lake Michigan.



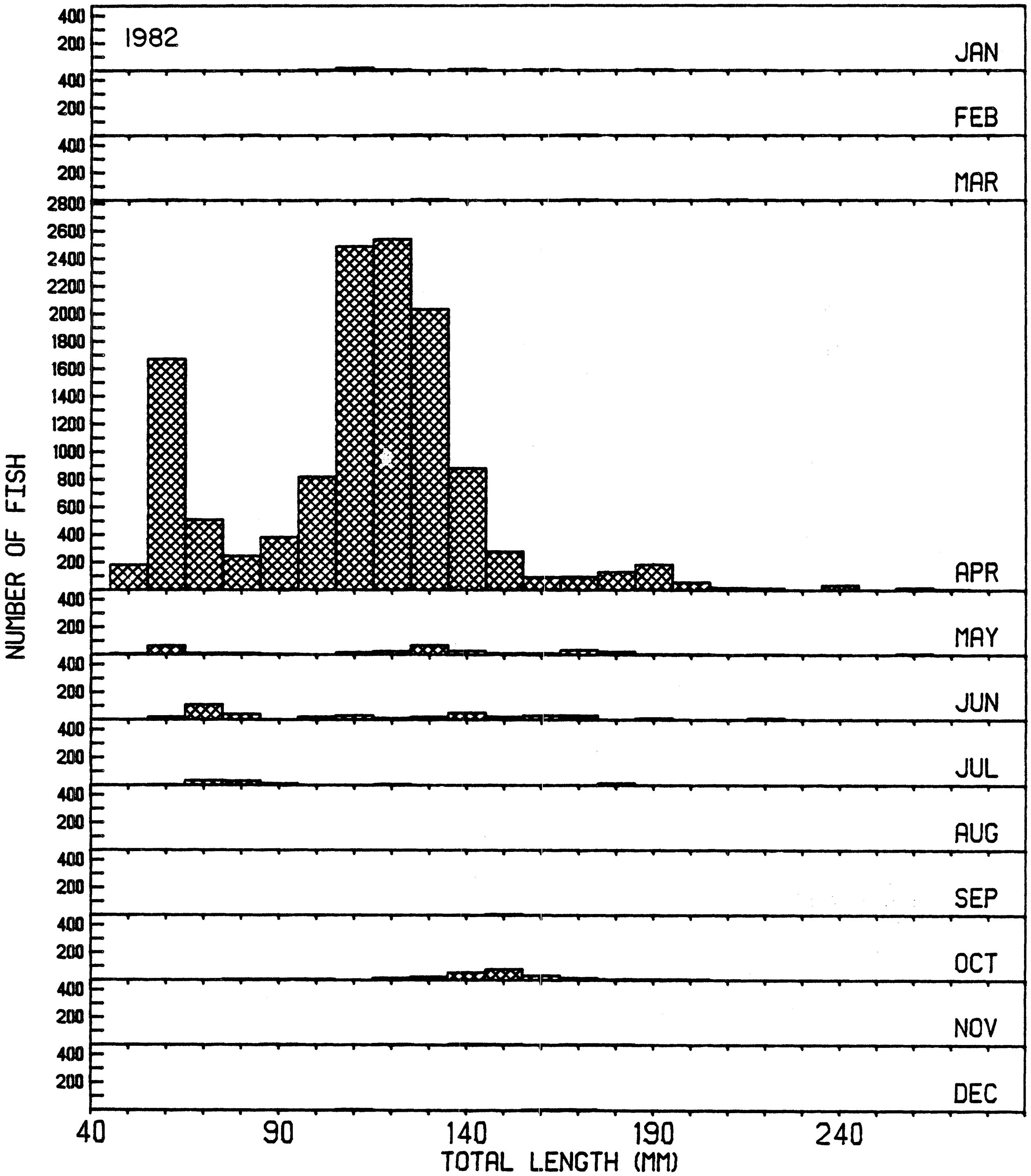
Appendix 84. Length-frequency histograms of rainbow smelt caught during 1980 field sampling at the Cook Plant, southeastern Lake Michigan.



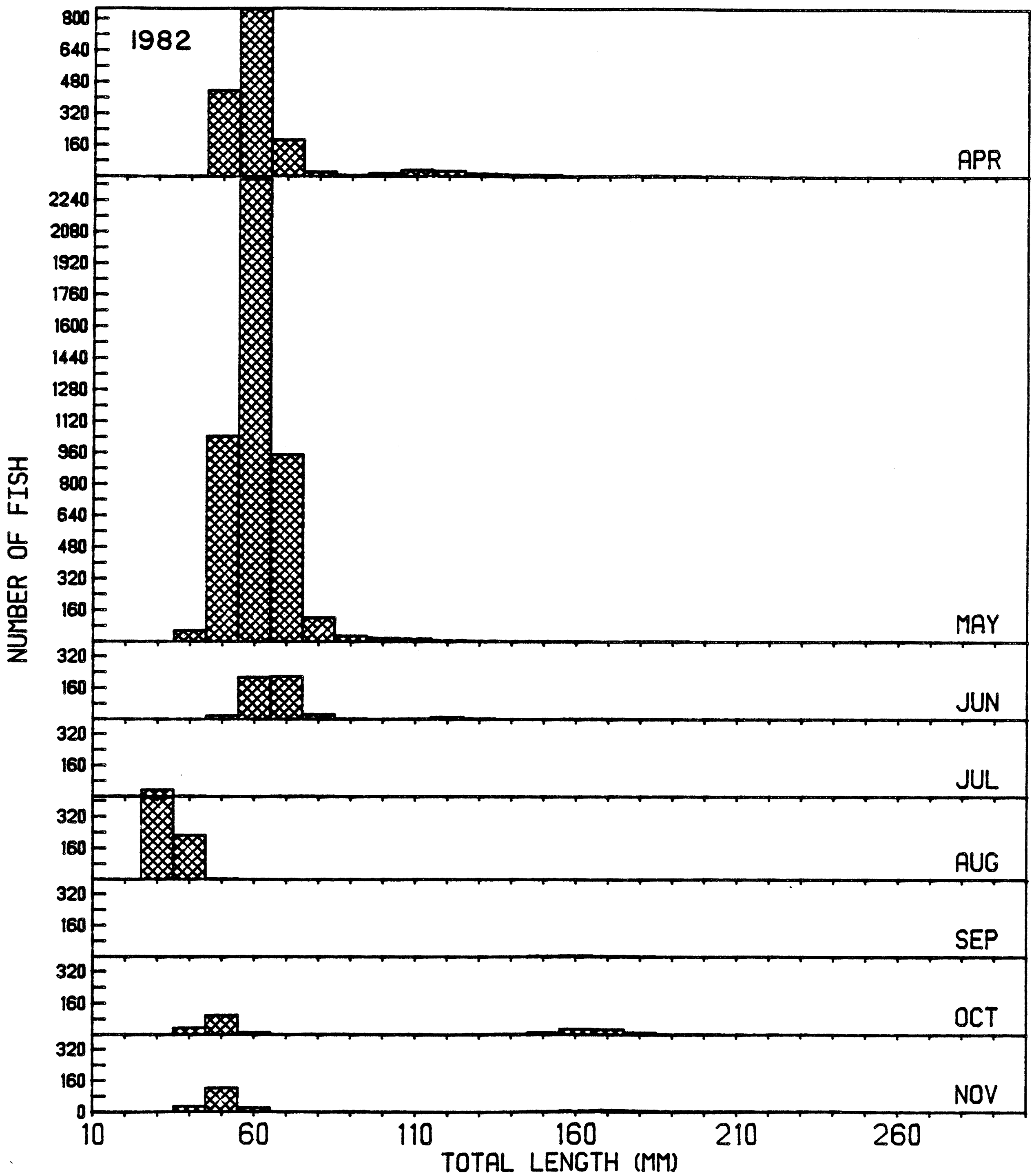
Appendix 85. Length-frequency histograms of rainbow smelt impinged during 1981 at the Cook Plant, southeastern Lake Michigan.



Appendix 86. Length-frequency histograms of rainbow smelt caught during 1981 field sampling at the Cook Plant, southeastern Lake Michigan.



Appendix 87. Length-frequency histograms of rainbow smelt impinged during 1982 at the Cook Plant, southeastern Lake Michigan.



Appendix 88. Length-frequency histograms of rainbow smelt caught during 1982 field sampling at the Cook Plant, southeastern Lake Michigan.